UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF WATER

December 2, 2022

Lieutenant General Scott Spellmon
Chief of Engineers
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314

Mr. Akis Gialopsos
Acting Commissioner
Alaska Department of Natural Resources
550 West 7th Avenue, Suite 1400
Anchorage, AK 99501

Ms. Michelle Johnson
Director
Chuchuna Minerals Company
11401 Olive Lane
Anchorage, AK 99515

Mr. John Shively
Chairman and CEO
Pebble Limited Partnership
2525 Gambell Street, Suite 405
Anchorage, AK 99503

Mr. John Shively
Director and President
Pebble East Claims Corporation
3201 C Street, Suite 404
Anchorage, AK 99503

Mr. John Shively
Director and President
Pebble West Claims Corporation
3201 C Street, Suite 505
Anchorage, AK 99503

Dear Lieutenant General Spellmon, Mr. Gialopsos, Ms. Johnson, and Mr. Shively

On December 1, 2022, I received from the U.S. Environmental Protection Agency's (EPA) Region 10 Regional Administrator Casey Sixkiller a Clean Water Act Section 404(c) Recommended Determination to prohibit and restrict the use of certain waters of the United States in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds as disposal sites for certain discharges of dredged or fill material associated with developing the Pebble deposit.

After evaluating the available information, including extensive scientific and technical information and the public comments received on the 2022 Proposed Determination, Regional Administrator Sixkiller determined that such discharges into certain waters of the United States in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds would be likely to result in unacceptable adverse effects on anadromous fishery areas.

EPA Region 10's Recommended Determination is available online at www.epa.gov/bristolbay.

EPA's Clean Water Act Section 404(c) regulations require EPA to initiate consultation with you at this stage and to offer you the opportunity to notify EPA, within fifteen (15) days, of your intent to take corrective action to prevent unacceptable adverse effects on anadromous fishery areas from discharges of dredged or fill material associated with developing the Pebble deposit. By this letter, consistent with the regulation at 40 C.F.R. § 231.6, EPA is initiating consultation with you. Should you decide to provide notification of your intent to take corrective action, please do so by December 19, 2022. Information previously provided to EPA Region 10 will be considered by EPA Headquarters and need not be resubmitted.

I appreciate your prompt attention to this matter. If you have any questions regarding the Recommended Determination or would like to arrange a consultation meeting, please have your staff contact Lynsey Lanier with the Office of Water, at (202) 566-1951 or Lanier.Lynsey@epa.gov or Laura Shumway with the Office of Wetlands, Oceans, and Watersheds, at (202) 566-2514 or Shumway.Laura@epa.gov.

Sincerely,

Radhika Fox
Assistant Administrator

CC: Mr. Casey Sixkiller, Regional Administrator, Region 10
EPA

Colonel Damon Delarosa
Commander, U.S. Army Corps of Engineers – Alaska District

Mr. David Hobbie, Chief of Regulatory Division
U.S. Army Corps of Engineers – Alaska District

Mr. John Crowther, Deputy Commissioner
Alaska Department of Natural Resources

Mr. Brent Goodrum, Deputy Commissioner
Alaska Department of Natural Resources

Mr. Robert Retherford, Director and Vice President
Chuchuna Minerals

Mr. Reeves Amodio, LLC, Registered Agent
Pebble East Claims Corporation and Pebble West Claims Corporation

APPENDIX B

ADDITIONAL INFORMATION RELATED TO THE ASSESSMENT OF AQUATIC HABITATS AND FISHES

APPENDIX B. ADDITIONAL INFORMATION RELATED TO THE ASSESSMENT OF AQUATIC HABITATS AND FISHES

Appendix B provides additional supporting information related to aquatic habitats within and downstream of the mine site in the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds and their role in supporting fish populations. As discussed in detail in Section 4, the impacts on aquatic resources that are predicted to occur from the 2020 Mine Plan, based on the available data (e.g., PLP 2011, PLP 2018a) and analyses reported in the Final Environmental Impact Statement (FEIS) (USACE 2020), would likely result in significant loss of or damage to fishery areas in the SFK and NFK watersheds. This appendix addresses additional issues related to two key points: (1) in many cases, the FEIS states that impacts would not result in significant adverse effects on aquatic resources, conclusions that often are not supported by the evidence provided in the FEIS; and (2) the impacts reported in the FEIS likely underestimate or underpredict the actual impacts that the 2020 Mine Plan would have on aquatic resources in the SFK, NFK, and UTC watersheds.

B.1 Quality, Importance, and Productivity of Lost Habitats for Fish Life Stages, Species, and Communities

As detailed in Sections 3 and 4 of this final determination, the evidence presented in the FEIS supports the U.S. Environmental Protection Agency's (EPA's) conclusion that aquatic habitats lost or degraded by the 2020 Mine Plan are of high quality, importance, and value as fishery areas.[1] This section provides an overview of EPA's approach and assumptions for assessing habitat quality and fish use when determining the "quality" of the stream habitats degraded by the 2020 Mine Plan and the "importance" or "value" of that lost habitat and altered functions for fish populations.

B.1.1 Assessing Stream Habitat Quality

The FEIS concludes that loss of stream habitats under the 2020 Mine Plan would be inconsequential for fish populations (USACE 2020: Section 4.24). This conclusion appears to be based on an assumption that the relative quality of these habitats is low and they have minimal influence on downstream waters. These assumptions and conclusions are not supported by the available information about these habitats (including information provided in the FEIS), or the current science surrounding the importance of headwater systems (Section 3.2.4, USACE 2020: Sections 4.16 and 4.24), their contributions to the

[1] A few commenters on the proposed determination cited specific FEIS conclusions as potentially contradicting EPA's conclusions in the final determination. See Attachment 1 of this appendix for the specific conclusions cited by commenters and a detailed discussion of why these FEIS conclusions do not contradict EPA's conclusions in the final determination.

spatial and temporal availability of aquatic resources (Section 3.3.3, USACE 2020: Sections 4.16 and 4.24), and the spatial and temporal scales at which those aquatic resources vary.

B.1.1.1 Quality of Lost Stream Habitats

The headwater streams draining the mine site were found to have low nutrient and dissolved organic carbon (DOC) concentrations (PLP 2018a: Appendix 9.1A), but these values do not suggest a low capacity to support biological productivity. Nutrient and DOC concentrations in downstream reaches and the mainstem Koktuli River generally are similar to those at the mine site (PLP 2018a: Appendix 9.1A). These mainstem habitats are productive salmon habitat, which highlights that nutrient and DOC concentrations are not the only or even most relevant indicators of biological productivity in this region.

According to the FEIS, streams that would be lost to the 2020 Mine Plan "…tend to have higher gradients, fewer off-channel and overwintering habitats, lower proportions of spawning gravels, and less woody debris…" (USACE 2020: Page 3.24-5) than downstream channels. In general, channels with gradients less than 3 percent most frequently meet the substrate and hydraulic conditions required by stream-spawning salmon (Montgomery and Buffington 1997, Montgomery et al. 1999). Many streams draining the mine site, particularly the smallest ones, do have gradients exceeding 3 percent (USACE 2020: Table 3.24-2); however, the anadromous fish stream losses under the 2020 Mine Plan (Table 4-1) are dominated by reaches with gradients less than 3 percent (USACE 2020: Table 3.24-2). Furthermore, the largest stream lengths affected, NFK tributaries 1.190 and 1.200, are documented in the FEIS as having gradients less than 3 percent and suitable spawning substrates (USACE 2020: Table 3.24-2). No data on off-channel habitats, woody debris, or overwintering habitats are reported for these tributaries, although off-channel habitats were quantified at mainstem sites (USACE 2020: Section 3.24, Table 3-10). As a result, FEIS conclusions about the quality of streams that would be lost under the 2020 Mine Plan, relative to downstream mainstem habitats, are not supported by evidence presented in the FEIS. This comparison between mainstem and tributary habitats also misrepresents the relationship between these habitats. Mainstems and tributaries perform overlapping, but not duplicative, roles—mainstem spawning habitats are productive because the headwaters that support them are currently undeveloped and undisturbed.

B.1.1.2 Downstream Effects of Lost Stream Habitats

Losses of stream habitats under the 2020 Mine Plan also will affect downstream waters, due to reduced inputs from lost upstream reaches. According to the FEIS,

> Based on project baseline surveys, the streams directly impacted in the mine site are not considered major contributors of marine-derived nutrients (MDN) from spawning salmon relative to downstream portions of the river network, making terrestrial nutrient sources relatively more important. This can be attributed to the comparatively small numbers of spawning fish, high flushing flows in the fall after spawning has occurred, and the lack of large woody debris or pool habitats for carcass retention (USACE 2020: Page 4.24-21).

As discussed in greater detail below (Sections B.1.2 and B.2.2), the project baseline surveys looked at highly variable spawning densities over only four or five spawning seasons (PLP 2018a: Chapter 15,

Tables 15-14 through 15-17). For this reason, these surveys provide a poor estimate of the temporal variation in spawning densities that has been observed in the region and may be expected over the time scales capturing the life of the mine and its attendant impacts (Rogers et al. 2013). In addition, the methods used to assess spawner abundance provide minimum estimates (Section B.1.2) of the abundance of spawners within a given reach and, thus, their potential contributions of marine-derived nutrients (MDN) to that reach.

The FEIS concludes, "There are abundant small headwater streams in the Koktuli River drainage that would be unaffected by mine site development, and would continue to provide downstream inputs important for stream productivity" (USACE 2020: Page 4.24-21). Although it is true that there are headwater streams that would remain unaffected and continue to provide downstream inputs, there would still be a loss of inputs from 91 miles of streams that support downstream anadromous habitats. The FEIS indicates that approximately 20 percent of available stream habitat in the Headwaters Koktuli watershed (i.e., the SFK and NFK watersheds) and 12 percent of available stream habitat in the larger Koktuli River watershed would be lost to the 2020 Mine Plan (USACE 2020: Section 4.24).[2] At both spatial scales, these impacts represent a considerable and unacceptable loss of upstream habitats that would necessarily affect downstream transport of energy and nutrients. Although the effects of these losses would be increasingly dampened as one moves farther downstream in the river network, reaches immediately downstream of the lost habitats would experience a complete loss of inputs from upstream habitats, which would necessarily affect their downstream transport of energy and nutrients. Thus, impacts to a specific downstream reach result not only from direct loss of headwater habitats under the 2020 Mine Plan, but also from how those direct losses cascade downstream through intervening reaches that are also affected by those direct losses.

B.1.2 Assessing Fish Distribution and Abundance

The SFK, NFK, and UTC are relatively well-sampled streams, compared with other streams in the region, due to Pebble Limited Partnership's (PLP's) efforts to collect environmental baseline data in areas draining the Pebble deposit area (PLP 2011, 2018a). However, accurately and comprehensively assessing fish distribution and abundance in stream and wetland habitats in the larger SFK, NFK, and UTC watersheds, as well as at the mine site area, is difficult. Because the region is inaccessible by road and subject to a challenging and variable climate, sampling occurs on intermittent site visits only during periods when the region and its aquatic habitats are accessible and effective fish sampling is possible. For example, densities of juvenile salmon in most of the tributaries that would be lost under the 2020 Mine Plan were only assessed in a single year (USACE 2020: Table 3.24-10). In addition, fish sampling efforts were not conducted during the winter, resulting in a lack of fish distribution and abundance information in overwintering areas. Given these logistical challenges, the currently available data provide an incomplete description of the full seasonal distribution and abundance of fish species and

[2] EPA acknowledges that water resources have not been consistently mapped throughout these watersheds (USACE 2020a: Page 4.24-8), which affects these percentage estimates. Nonetheless, the 2020 Mine Plan would result in the permanent loss of nearly 100 miles of headwater streams.

life-history stages across the region's high diversity and density of aquatic habitats. Because habitat use by fishes is highly variable in space and time, and because all habitats in the region have not been sampled for all species and life stages, in all seasons, over multiple years, it is reasonable to conclude that the data provide an underestimate of the distribution and abundance of fish species and life stages within these habitats.

This likely underestimation of fish distributions is true not only of the data reported by PLP (2011, 2018a), but also of the Anadromous Waters Catalog (AWC) (Giefer and Graziano 2022) and the Alaska Freshwater Fish Inventory (AFFI) (ADF&G 2022a). These databases do not characterize all potential fish-bearing streams due to the large number of and lack of access to streams in Alaska. The AWC and the AFFI are not comprehensive, meaning that not all streams have been sampled and unsampled streams cannot be assumed to be non-fish bearing. The AWC website acknowledges this limitation, stating that the database "…lists almost 20,000 streams, rivers, or lakes around the state which have been specified as being important for the spawning, rearing or migration of anadromous fish. However, based upon thorough surveys of a few drainages it is believed that this number represents a fraction of the streams, river, and lakes actually used by anadromous species" (ADF&G 2022b). Even within the footprint of the 2020 Mine Plan, the FEIS indicates that the majority of mapped streams have not been sampled for fish (USACE 2020: Section 4.24, Figure 4.24-1). Similarly, life stage-specific designations in the AWC likely represent underestimates, given the challenges inherent in surveying all streams that may support life-stage use throughout the year. These same challenges—and thus likely underestimation of habitat use—also pertain to other aquatic habitat types (e.g., wetlands and other off-channel habitats).

Moreover, the methods used to assess fish distribution and abundance have included several sampling techniques, including snorkeling, electrofishing, seining, angling, and visual observation (aerial and on-the-ground). All of these methods have limitations. Aerial surveys of spawning salmon only account for a portion of the spawning populations, and estimates based on these surveys should be considered minimum counts (Jones et al. 2007, Morstad et al. 2009). Many of these methods, as applied, appear to lack quantitative estimates of capture efficiency: for example, PLP (2011) acknowledges that many of the methods used "were not conducive to estimate catch-per-unit-effort (CPUE)" (PLP 2011: Chapter 15). As a result, estimates of abundance or density with confidence bounds cannot be derived, these methods are most useful for estimating presence of species and life-history stages, and any estimates of distribution and abundance derived from such methods are necessarily minimums because fish species may use certain habitats at times of the year other than when sampling has been conducted to date.

B.1.3 Assessing Habitat Importance or Value

The importance of individual streams and wetlands is not fully captured by fish presence. Stream and river fishes depend on the interconnected suite of watershed processes that shape physical habitat, structure the flow of energy through the system, provide the trophic basis for growth, and regulate the chemical, physical, and biological conditions experienced by fishes and other aquatic life. As discussed in Section 3.2.4, headwater streams and wetlands and their associated functions are crucial contributors to

the quality of downstream waters inhabited by fishes, even if those habitats do not themselves contain fish (Cummins and Wilzbach 2005).

Where fishes are observed in headwater streams and wetlands, density is not always a reliable indicator of habitat quality or productive potential. PLP has undertaken a significant effort to assess fish populations in the SFK, NFK, and UTC watersheds (PLP 2011, 2018a), and the resulting data provide useful baseline information. However, these data are insufficient to conclude that aquatic habitats with no or low fish densities are unimportant for supporting and maintaining fishery resources over the lifespan of potential impacts under the 2020 Mine Plan.

Productivity for Pacific salmon, sometimes defined as the ratio of recruits or offspring per spawner, varies over space and time (Rogers and Schindler 2008). Based on evidence that the component watersheds and associated marine waters yield large quantities of salmon biomass annually, the Bristol Bay watershed—including the SFK, NFK, and UTC watersheds—is highly productive. Watersheds with a high capacity to support salmon production will not always contain high densities of fish at all given times and locations, for numerous reasons (Warren 1971, Van Horne 1983). This may be particularly true for anadromous salmonids and other fish species (e.g., Northern Pike) that use an array of habitats to complete their life cycles. For these species, local abundances may be influenced by population dynamics that occurred elsewhere, during an earlier life stage.

Salmon populations may cycle at decadal to centennial scales (Rogers et al. 2013), and locations of high salmon productivity in the region shift in time and space (Brennan et al. 2019). Some aquatic habitats are seasonally important: salmon may be present in high abundances at certain times of the year, and absent at other times. Some aquatic habitats may have no or low abundances of salmon in some years, but high abundances in other years, reflecting how populations respond to changing environmental conditions across habitats (Section 3.3.3). This variability is illustrated by annual differences in aerial counts of salmon spawners in the SFK, NFK, and UTC mainstems between 2004 and 2008 (PLP 2018a: Table 3-7). Highest index spawner counts differed substantially across species and years, with no consistent pattern across sites: for example, the maximum highest index spawner count for Chinook Salmon occurred in 2004 in the SFK but in 2005 in the NFK (Table 3-7). These data show how variable counts are over a 5-year period. Over longer time scales, this variability is even greater. Available data for total inshore Sockeye Salmon runs in Bristol Bay illustrate this point. Between 2004 and 2008, the period during which most of the fish abundance and distribution data reported in the FEIS were collected, Bristol Bay's total inshore run of Sockeye Salmon ranged from 39.4 million to 44.8 million fish (Tiernan et al. 2021). In 2022, the total inshore run of Sockeye Salmon was 79.0 million fish (ADF&G 2022c)—a roughly 100 percent increase from 2004 through 2008 values. This significant increase in Bristol Bay's Sockeye Salmon runs over the past decade is not captured in the fish abundance and distribution data used to estimate impacts in the FEIS.

These same patterns of spatial and temporal variability also apply to other fish species, macroinvertebrates, and other components of the food web essential for ecosystem function. Given these considerations and the spatial and temporal limitations of the available data, it is impossible to

conclude with any certainty that the aquatic habitats lost to the 2020 Mine Plan are not and would not be important to Pacific salmon over the life of the mine and beyond.

B.1.4 Summary

PLP (2011, 2018a) presents results of the most extensive fish-sampling regime that currently has been conducted in the SFK, NFK, and UTC watersheds. These data show that streams in these watersheds, including those that will be lost under the 2020 Mine Plan, provide spawning and rearing habitat for multiple Pacific salmon species. However, limitations of the sampling regime mean that these data provide an incomplete description of—and likely underestimate—actual seasonal fish distributions and abundances in the region. Aquatic habitats at the mine site and in downstream mainstem reaches, including lateral floodplain habitats, vary in importance across species and life stages, both seasonally and annually (see Section B.2.2). Given these factors, EPA cautions against making conclusions that certain habitats are not important based solely on the numbers of fish observed under PLP's sampling regime. The quality of a given aquatic habitat as a fishery area does not depend solely on fish abundance within that habitat, particularly when fish abundance is assessed infrequently and over limited time scales. Many other factors, including the contributions that habitat makes to the quality and maintenance of downstream reaches, determine the importance of aquatic habitat as fishery areas. It is not valid to conclude that aquatic habitats with no or low observed fish abundances under the sampling regime conducted to date are somehow unimportant as, or unimportant in maintaining, fishery areas. The measure of value, importance, or significance of a given habitat includes not just the fish found there at a specific point in time, but also the fish that have used those habitats in the past, those that will use those habitats in the future, and the larger watershed functions to which that habitat contributes. The headwater streams and wetlands that would be impacted by the 2020 Mine Plan are, in fact, very important for Pacific salmon and other fishes, both directly by providing fish habitat at particular times (i.e., in specific years or seasons, or for specific life stages) and indirectly by provisioning and regulating downstream fish habitats (Section 3.2.4). As a result, these habitats are integral parts of their immensely productive watersheds.

B.2 Spatial and Temporal Scales and Variability

This section examines the importance of (1) considering the spatial and temporal scales at which potential effects of the 2020 Mine Plan on aquatic resources are evaluated, and (2) sufficiently capturing and considering spatial and temporal variability in environmental parameters and aquatic resources when evaluating those effects.

B.2.1 Spatial and Temporal Scales Used in Assessment of the 2020 Mine Plan

When conducting an assessment, defining and selecting appropriate spatial and temporal scales for the analysis are essential. Assessments and models evaluate the system of inquiry at specific spatial and temporal scales, which may be explicitly or implicitly determined. The selection of scales of inquiry is

critical, as they must be appropriate to capture biologically and ecologically meaningful patterns and processes (Levin 1992). Often, the identification of meaningful and relevant impacts to resources of concern requires that assessments consider impacts at multiple scales.

In evaluating potential effects of the 2020 Mine Plan on fish populations, an appropriate spatial scale would capture the extents of adult spawning, egg incubation, juvenile rearing and seasonal movement, and migration as potentially affected by changes in chemical, physical, or biological conditions or processes at and downstream of the mine site. For mine site development and operations, this spatial scale would include all waters under the mine footprint and extend downstream as far as effects could be measured or reasonably expected to have ecological consequences. For example, the spatial scale might be determined by the downstream extent that key constituents were altered for chemical changes and that fluvial geomorphic processes were altered for physical changes. Pacific salmon, due to their mobile and migratory nature, use habitats across these spatial scales over the course of their life cycles.

This selection of appropriate scale is important because assessment of whether "measurable impacts" occur is scale dependent. For example, if an assessment considers a large-enough spatial scale, relative to the assessed area, when evaluating impacts, the relative magnitude of those impacts will diminish as a function of increasing scale (although the absolute magnitude of those impacts remains unchanged). If an assessment considers a short enough temporal scale, relative to the life histories of the species affected and the time frames over which habitat use by species and life stages vary, when evaluating impacts, it may fail to detect what over longer time periods becomes irreparable harm to those habitats and populations (Schindler and Hilborn 2015). Thus, assessment of effects should be conducted at spatial and temporal scales that are most relevant to the resources being evaluated (EPA 2019a, EPA 2019b).

This scale-dependence is illustrated clearly in the FEIS, which concludes that "impacts to Bristol Bay salmon are not expected to be measurable" (USACE 2020: Page 4.24-7). This statement presupposes that the only scale at which impacts matter is the entire Bristol Bay watershed—that is, only impacts at the level of the entire Bristol Bay salmon population are important. Reporting conclusions about impacts at this regional scale results in impacts appearing to be less severe, relatively. The direct loss of 99.7 miles of streams within the initial 2020 Mine Plan footprint is reported as "…about 20 percent of available habitat in the Headwaters Koktuli drainage [i.e., the SFK and NFK watersheds], 12 percent of available habitat in the larger Koktuli River drainage, and 0.3 percent of available stream and river habitat in the Nushagak watershed" (USACE 2020: Page 4.24-8). Basing conclusions on relative effects at the largest spatial extent suggests that individual habitats and the fishes they support are similar and interchangeable throughout the Nushagak River watershed, and evidence suggests that is not the case (Section 3.3.3). It also does not change the fact that 99.7 miles of streams in the SFK, NFK, and UTC watersheds would be lost under the 2020 Mine Plan footprint, an amount of loss that will have an unacceptable adverse effect on fishery areas in these watersheds (Section 4.2.1).

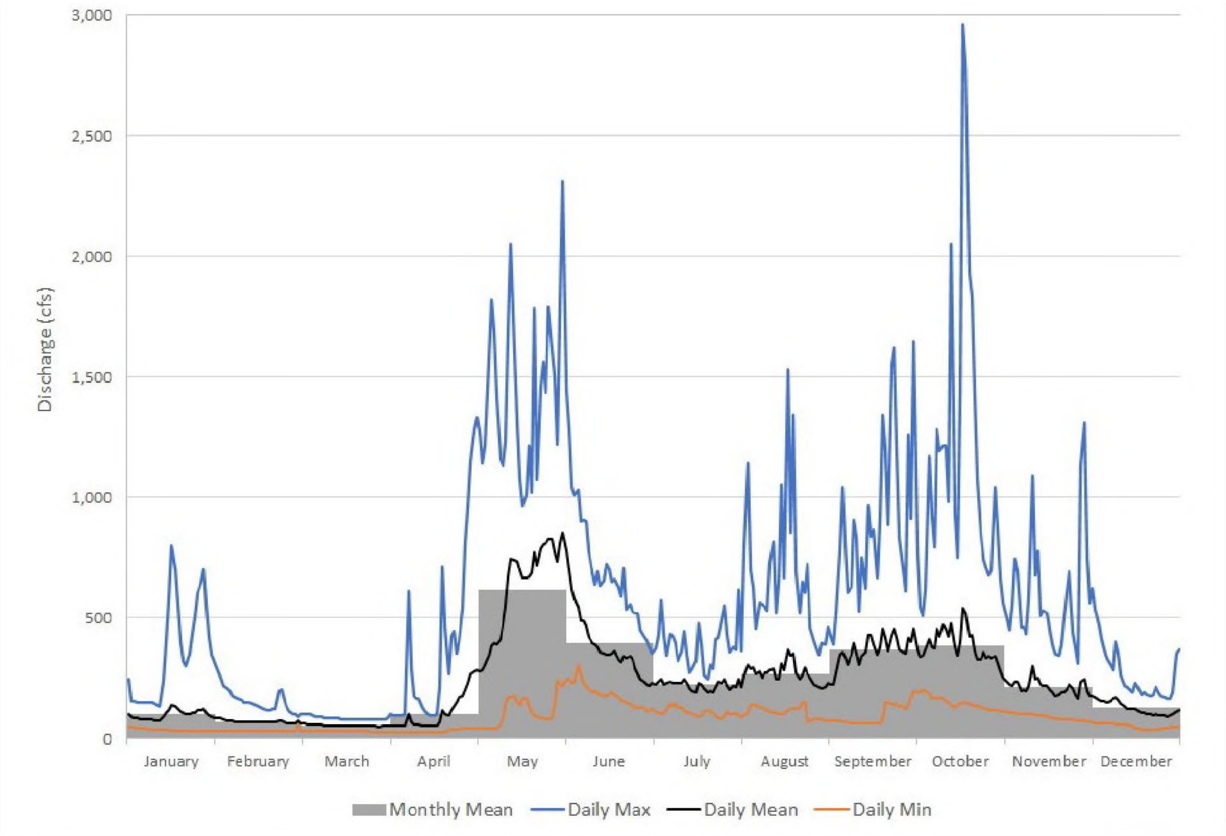
Ninety-four percent of the 2020 Mine Plan's impacts to streams, wetlands, and other aquatic resources would occur in the Koktuli River watershed. The miles of streams and acres of wetlands and other

waters that would be lost reflect local conditions and provide habitat to specific fish communities that are part of a portfolio of local populations of multiple Pacific salmon and other fish species (Section 3.3.3). Thus, the FEIS conclusion does not disclose impacts at the smaller, more relevant and appropriate scale where impacts would be measurable. Loss of any genetically distinct populations in the Koktuli River watershed would constitute a measurable, adverse effect, in addition to any effects these losses may have at the entire Bristol Bay watershed scale via the portfolio effect (Section 3.3.3).

Selection of appropriate temporal scales is also important for evaluating impacts to fishes and their habitats. For example, the FEIS presents streamflows and estimates of streamflow change in terms of average monthly flows (USACE 2020: Section 4.16, Table 4.16-3). Although hydrologists consider average monthly flows to be a meaningful measure of a stream's hydrograph, evaluating impacts of streamflow changes at a monthly temporal scale does not address key ecological considerations relevant to fishes. A stream's annual hydrograph can be characterized by monthly averages, the annual extremes of low and high flows, and short-duration flow pulses (Richter et al. 1996, George et al. 2021). A stream's hydrograph may also be characterized by components that include baseflow, frequent floods, seasonal timing of flows, and interannual variation in flow. In all cases, the magnitude, timing, duration, frequency, and rate of change of streamflows are important in characterizing the natural hydrograph (Poff et al. 1997).

The life histories and behaviors of aquatic organisms are attuned to streamflow cues at different timescales and may be affected by daily (and even sub-daily) variations in streamflow that affect physical and ecological processes (Bevelhimer et al. 2015, Freeman et al. 2022). The use of monthly averages without consideration of daily and interannual variation ignores impacts of predicted flow changes on other important streamflow components. Evaluating streamflow changes using only average monthly flows masks the severity of impacts, because percent changes in daily flows are more variable than changes to monthly averages. This dampening of variability is clearly illustrated by comparing average daily to average monthly flows (Figure B-1): during both low flow and high flow periods, average monthly streamflow does not capture the range of flows that occur in the system. However, such daily flow information is not reported or analyzed in the FEIS. Evaluating streamflow changes using monthly averages provides only a minimum estimate of the actual streamflow changes likely to result from the 2020 Mine Plan. The same is true for changes in water temperature, which the FEIS also presents as monthly averages grouped by winter and summer months (USACE 2020: Section 4.24, Table 4.24-3). The FEIS acknowledges that the potential for daily temperature variations beyond the monthly ranges exists, but states, without any supporting evidence, that the monthly ranges are representative of potential temperature changes (USACE 2020: Section 4.24).

Figure B-1. Average monthly versus minimum, average, and maximum daily streamflow in the North Fork Koktuli River. Averages are based on data at site NK100A (USGS Gage #15302250), from 2004–2015 (USGS 2022).



B.2.2 Spatial and Temporal Variability in Assessment of the 2020 Mine Plan

Streams and rivers are dynamic, highly variable systems. Oversimplification of this variability, or failure to account for rare, but disproportionately influential, spatial features or temporal events, can lead to faulty conclusions. In streams and rivers, infrequent but extreme flow events (i.e., floods or droughts) can strongly shape ecology. The timing and duration of ecologically important flow events, for example, can be difficult to predict, but can profoundly affect both physical habitat structure and population dynamics (Poff et al. 1997, Freeman et al. 2022). Similarly, uncommon or infrequent habitat features can be disproportionately important. For example, shelters or refuges from environmental conditions that may be briefly limiting can serve as "bottlenecks," constraining the abundance of future life stages; for Pacific salmon, critical "bottleneck" habitats can include off-channel habitats and beaver ponds (Pollock et al. 2004).

To fully consider this variability in an assessment of potential impacts, all components of these aquatic systems (i.e., chemical, physical, and biological) should be sampled over spatial and temporal extents that capture the full range of variability in each component. In addition, connectivity between headwater streams and wetlands and downstream waters is dynamic, shifting on both short-term and long-term time frames in response to changing environmental conditions (Fritz et al. 2018). A complete accounting of how headwaters affect downstream waters should consider aggregate physical, chemical, and biological connections over multiple years to decades (Fritz et al. 2018, Schofield et al. 2018).

A significant amount of baseline environmental data has been collected in the SFK, NFK, and UTC watersheds, primarily between 2004 and 2008 (PLP 2011, 2018a). These data demonstrate the natural variability of these systems, in terms of biological communities, streamflow, water chemistry, and myriad other factors, across both sites and sampling dates (e.g., see discussion of adult salmon spawner counts in Section B.1.3). There is no reason to expect that these data, primarily collected over a 5-year period nearly 15 years ago, fully capture how much these factors vary over longer time scales and more finely resolved spatial scales. The nearly 100 percent increase in Bristol Bay's total inshore Sockeye Salmon run in 2022 (ADF&G 2022c), relative to runs between 2004 and 2008 (Tiernan et al. 2021), provides just one example of the variability in environmental conditions that has not been captured in the FEIS and, thus, not considered in its evaluation of impacts of the 2020 Mine Plan.

Streamflow data provide another illustration of this point. Accurate quantification of streamflow metrics requires data collected over sufficient areas and time periods to account for spatial and temporal variability (George et al. 2021). Multiple studies have shown that streamflow data collected over a limited number of years are associated with high levels of uncertainty (Kennard et al. 2010, Goguen et al. 2020). For example, Goguen et al. (2020) evaluated the variability of flow metrics calculated with data collected over different time periods. They found that uncertainty or variability (measured as coefficient of variation) in monthly flow metrics was 30 percent when metrics were calculated over 5 years but decreased rapidly when metrics were calculated over 15 or more years (Goguen et al. 2020).

The high natural variability of these systems also makes FEIS claims that impacts of the 2020 Mine Plan would not be significant because they "would be expected to fall within the range of natural variability" (e.g., USACE 2020: Page 4.24-46) meaningless. This is easily illustrated by considering streamflow variability in Figure B-1. Between 2004 and 2015, average daily streamflow at NK100A, the downstream-most site on the NFK mainstem considered in the FEIS, ranged from roughly 0 to 3,000 cfs; in May alone, average daily streamflow ranged from 40 to more than 2,000 cfs (Figure B-1). Streamflow changes that occur within this range of "natural variability" could still have significant impacts on aquatic resources if they are occurring more or less frequently than under natural, undisturbed conditions.

Like streamflow, fish populations can be highly dynamic in time and space, limiting the ability of short-term, spatially unbalanced sampling designs to adequately characterize population dynamics that may be important for long-term persistence (Davis and Schindler 2021). The baseline data on fish abundance and distribution used in the FEIS were primarily collected between 2004 and 2008, and many sites were

not sampled in multiple seasons across multiple years; thus, data were not collected over sufficient spatial and temporal scales to fully characterize the bounds of the natural spatial and temporal variability of fish populations in the region, for all species and life stages, to adequately support the FEIS conclusions about impacts to fishes. Based on 57 years of continuous monitoring data, Davis and Schindler (2021) conclude that long-term assessments are needed to fully understand the contributions of individual populations. The FEIS assessment of fish abundance and habitat use relies on data collected over a much shorter time period. As a result, FEIS conclusions about the long-term impacts on aquatic resources resulting from the 2020 Mine Plan based on these data should be viewed as minimum estimates—and, as detailed in Section 4.2, even these minimum estimates constitute an unacceptable adverse effect on fishery areas.

B.3 FEIS Assessment of Streamflow Changes

The models and methods used in the FEIS to estimate streamflow changes in the SFK, NFK, and UTC watersheds associated with the 2020 Mine Plan have several shortcomings. This section summarizes the FEIS conclusions regarding streamflow and identifies several issues with those conclusions or the underlying methods, many of which EPA expressed throughout the EIS development process (e.g., EPA 2019a, EPA 2019b).

The FEIS presents impacts of the 2020 Mine Plan that were estimated using an end-of-mine watershed model that incorporated inputs from three primary components: a baseline watershed model, a groundwater flow model, and a mine-site water-balance model (PLP 2019a: RFI 109g). Streamflow changes are reported in terms of changes in average monthly streamflow between baseline (i.e., under natural conditions) and end-of-mine, assuming discharge of treated water in an "average climate year" (i.e., at a 50-percent exceedance probability), based on 76 synthetic monthly average flows (USACE 2020: Section 4.16 and Appendix K4.16) calculated from runoff estimates derived from long-term precipitation and temperature data at a site roughly 17 miles from the mine site. The FEIS states that water would be strategically discharged from wastewater treatment plants (WTPs) to benefit a priority fish species (Chinook Salmon, Coho Salmon Sockeye Salmon, Rainbow Trout, or Arctic Grayling) and life stage (spawning or juvenile rearing) selected for each month in each watershed (USACE 2020: Table 4.24-2).

As detailed in Section 4.2.4, downstream flow changes associated with the 2020 Mine Plan, as reported in the FEIS (USACE 2020: Section 4.16), would exceed 20 percent of average monthly flows in at least 29 miles of documented anadromous fish streams. Reaches of the SFK and NFK closest to the mine site would experience greater changes in average monthly streamflow than reaches farther downstream (USACE 2020: Section 4.16). NFK Tributary 1.190 would be dewatered entirely—that is, experience a 100-percent loss of flow—due to construction of the bulk tailings storage facility and seepage-collection system (USACE 2020: Section 4.16). SFK Tributary 1.190 is predicted to experience a maximum change in average monthly flow of 19 percent during operations, whereas SFK Tributary 1.24 is predicted to

experience a maximum change of 98 percent (USACE 2020: Section 4.16). A total of 9.2 miles of anadromous habitat have been documented within these two SFK tributaries.

Significant streamflow alterations also would extend down the NFK and SFK mainstems. For example, NFK Reaches A, B, and C would experience a greater than 20-percent increase in streamflow during April; NFK Reach C could see a 105-percent increase in April and a 20-percent decrease in June. These alterations are predicted to occur despite attempts to "optimize" the discharge of treated water to benefit priority fish species and life stages. SFK Reach E would see a 52-percent decrease in average monthly streamflow in April, whereas SFK Reach D would see a 109-percent increase (USACE 2020: Table 4.16-3) due to WTP discharges. According to the FEIS, the extent of impacts on streamflow could extend to just below the confluence of the SFK and NFK (USACE 2020: Page 4.16-2),[3] meaning that up to 61 miles of the SFK and NFK mainstems could experience "discernible" streamflow alterations. This level of change from natural streamflows represents an unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2.4).

Despite the importance of natural flow regimes as a "master variable" determining the structure and function of stream and river ecosystems (Bunn and Arthington 2002, Lytle and Poff 2004, Poff and Zimmerman 2010, Sofi et al. 2020, Tonkin et al. 2021), the FEIS fails to evaluate the myriad ways that anticipated streamflow changes would affect these systems. The FEIS also likely underestimates the actual extent to which streamflow in the SFK, NFK, and UTC watersheds would be affected by mine operations resulting from the 2020 Mine Plan, in terms of percentage change in streamflow, length of affected streams, and changes in streamflow variability. This underestimation of streamflow changes in the FEIS results from several issues.

The following sections highlight three specific areas of concern in the FEIS assessment of streamflow changes: the failure to consider ecological impacts of streamflow changes; the use of average monthly streamflows to assess impacts; and the failure to sufficiently consider interactions between surface waters and groundwater.

B.3.1 Impacts of Streamflow Changes

The natural flow regime is a critical component of streams and rivers and their hydrologically connected aquatic habitats because water flow directly or indirectly affects all other physical, chemical, and biological components of these systems (Bunn and Arthington 2002, Lytle and Poff 2004, Poff and Zimmerman 2010, Sofi et al. 2020, Tonkin et al. 2021). The body of published scientific literature on the functional consequences of hydrograph alteration is extensive (e.g., Poff et al. 1997, Tonkin et al. 2021, Freeman et al. 2022). Despite its importance, the FEIS does not address the numerous effects of predicted flow changes directly. There is no explanation of how streamflow changes associated with the

[3] The FEIS indicates streamflow in the UTC and the Koktuli River below the confluence of the NFK and SFK would not be negatively impacted by the project (USACE 2020: Section 4.24).

2020 Mine Plan would affect natural flow patterns and variability,[4] nor consideration of how these streamflow changes would alter physical habitat, water quality, and the full suite of organisms adapted to natural flows in these systems (Section B.5.2).

The FEIS instead uses estimates of streamflow change solely to inform its fish habitat modeling, presenting summaries of monthly changes to "suitable fish habitat" as defined in the PHABSIM model (Section B.4). Flow changes that alter monthly averages by more than 100 percent are viewed only through the lens of the PHABSIM model and are predicted to increase available habitat, notwithstanding the elimination of nearly 100 miles of streams and the myriad effects the loss of these flows and their ecological subsidies would have on downstream reaches. There is no distinction made in the FEIS between flows that create and maintain habitat (e.g., channel-maintenance flows) and those that affect habitat utilization. As a result, the FEIS presents an extremely simplified assessment of how streamflow changes will affect mainstem and tributary reaches of the SFK, NFK, and UTC watersheds. As detailed in Section 4.2.4, even this simplified assessment shows that streamflow alterations associated with the 2020 Mine Plan would constitute an unacceptable adverse effect on fishery areas, and the actual ecological impact of these changes would likely be more extensive than estimated in the FEIS.

Furthermore, stream lengths in which flow regimes would be significantly altered from natural conditions are not quantified or discussed in the FEIS. The FEIS states that flow changes may extend to reaches just below the confluence of the SFK and NFK mainstems (USACE 2020: Page 4.16-2), but the FEIS does not mention that there are 61 miles combined in the SFK and NFK mainstems before reaching that confluence. Additionally, the distance between locations at which streamflow information was collected and modeled limits the ability to accurately predict the extent of streamflow impacts. For example, WTP discharges to Frying Pan Lake would increase outflows to the SFK up to 109 percent above average monthly flows. However, it is unclear how far downstream these flow increases would extend because the next downstream gage at which streamflow information was estimated (i.e., SFK Reach C) is located 11.7 river miles downstream. At that point, streamflow changes were estimated at less than 5 percent below baseline average monthly flow (USACE 2020: Table 4.16-3).[5] The actual extent of streamflow changes in the SFK most likely extends some distance downstream of Frying Pan Lake, but the FEIS does not provide an estimate of that distance.

[4] The FEIS acknowledges that "[f]lood magnitude and frequency on the NFK and SFK rivers could potentially change as a result of mine development" and that "[t]he geographic extent of potential changes to flood magnitude on the NFK and SFK could extend just below the confluence of the two rivers," (USACE 2020: Page 4.16-18), but does not discuss how specific flood events, such as channel-forming flows or bankfull flows that occur every 1.5 to 2 years, would be altered; what such changes would mean for stream stability; or how such changes would affect aquatic habitats and species.

[5] The next downstream location for which streamflow data are presented in FEIS Table 4.16-3 is SFK Reach C, which is based on streamflow at gage SK100C (PLP 2019b: RFI 109f), 11.7 river miles (18.9 km) downstream of SK100F (PLP 2020d: RFI 161).

B.3.2 Use of Average Monthly Flows and Climate Conditions

The FEIS presents streamflows and estimates of streamflow change in terms of average monthly flows (USACE 2020: Section 4.16, Table 4.16-3). Percentage flow differences between baseline and end-of-mine conditions are computed based on monthly averages, which as discussed below provide a relatively coarse measure of potential impacts to fishes and other aquatic resources. Even at this coarse level of assessment, greater than 20 percent changes in average monthly flows are predicted during at least 1 month per year in at least 29 miles of documented anadromous fish streams.

In reality, the use of average monthly flows to evaluate impacts of the 2020 Mine Plan likely underestimates downstream flow changes that would have meaningful ecological effects. Average monthly flows do not capture ecologically important aspects of the natural hydrograph (Section B.2) or represent the full magnitude of potential daily flow fluctuations. As a result, the use of monthly averages downplays the extent of impacts on the natural hydrograph and the aquatic life that is adapted to and relies on it. Fish do not experience average monthly flows; rather, they experience the dynamic continuum of flows occurring over much shorter time periods (i.e., daily or even sub-daily flows). As discussed in Section B.2.1, evaluation of streamflow changes using only average monthly flows masks the severity of impacts, because percent changes in average monthly flows are less variable than changes in daily flows (Figure B-1). If average monthly streamflows differ from baseline conditions, aquatic resources are likely to be altered; if average monthly streamflows do not differ from baseline conditions, it does not necessarily mean that streamflow patterns on shorter time scales—and, thus, aquatic resources—will not be affected.

In the FEIS analysis of streamflow changes, WTP discharges would be preplanned for each month based on modeling and a set of assumptions. Monthly WTP discharges would be the amount needed to “optimize” downstream habitat for specific anadromous fish species and life stages assuming that the historic monthly average streamflow was to occur (i.e., given an “average climatic year,” or 50 percent exceedance probability). However, the only monitoring proposed by PLP appears to be quarterly streamflow and fish presence surveys (PLP 2019c: RFI 135), indicating that water discharges were never proposed to be altered in response to current climatic conditions. Managing water discharges based on average long-term streamflows would dampen variability in the system (Section B.2.2). The proposed discharges would transform the naturally varying and unregulated surface water and groundwater flows in the headwaters into uniform, regulated process-water discharges to surface waters. The loss of this streamflow variability, which is critical to the structure and function of these ecosystems (Poff et al. 1997, Bunn and Arthington 2002, Freeman et al. 2022), is not described or characterized in the FEIS.

Despite these shortcomings, the streamflow change estimates documented in the FEIS provide a reasonable minimum approximation of the streamflow impacts expected to result from the 2020 Mine Plan. Even these minimum estimates of changes in average monthly flows, over the stream lengths documented in the FEIS, would affect the physical, chemical, and biological characteristics of these streams and constitute an unacceptable adverse effect on fishery areas.

B.3.3 Interactions between Groundwater and Surface Waters

As discussed in Section 3.2.1, surface waters and groundwater in the SFK, NFK, and UTC watersheds are highly connected and interact in complex ways (USACE 2020: Section 3.17). These interactions influence streamflow patterns—and thus aquatic resources—in both space and time. The FEIS provides limited characterization or simulation of the coupled surface water-groundwater interactions critical to maintaining the region's aquatic ecosystems (Wobus and Prucha 2020). As a result, the FEIS underestimates the extent of groundwater impacts likely to occur under the 2020 Mine Plan and, thus, potential effects on downstream flows. Examples of the failure of the FEIS to adequately consider groundwater impacts and interactions with surface waters are included below.

- The baseline watershed model and the groundwater flow model used to assess streamflow changes were not integrated, and instead they were developed and operated independently (Wobus and Prucha 2020). The baseline watershed model was configured and calibrated prior to development of the refined groundwater model (MODFLOW). Together, these points indicate that estimates of streamflow change in the FEIS did not represent a comprehensive, integrated assessment of how changes in both surface waters and groundwater would affect streamflows under the 2020 Mine Plan.

- A review of the model calibration shows the groundwater model overestimates groundwater elevation in the NFK headwaters area and underestimates NFK streamflow downstream of the headwaters, which may be an indication of poor model calibration (PLP 2019d: RFI 109d). MODFLOW simulations resulted in groundwater elevations that were up to 35 feet deeper than observed water table elevations (e.g., Figure 6-10 in PLP [2019d]), suggesting poor model calibration and the need to expand the alluvial aquifer in the headwaters of the NFK to properly account for groundwater and surface water observations.

- Within and across the mine site boundary, streamflow changes due to well pumping and groundwater table depression were not well characterized. Streamflow losses during mine operation were only characterized by conditions at the end-of-mine (e.g., 20 years). Changes in shallow groundwater conditions and associated stream losses within and across the mine site boundary were not rigorously accounted for when estimating streamflow impacts, as indicated by the significant differences between MODFLOW's simulated groundwater elevations and observed groundwater elevations (discussed above). Impacts on gaining reaches downstream of the mine, attributed to groundwater sources under pre-mine conditions in the FEIS, were not considered.

- The majority of surface water and groundwater flows within the mine site boundary were assumed to be captured, contained, and released via WTP discharge to surface waters. There was no assessment of impacts associated with the loss of groundwater recharge at the mine site, which provides baseflow contributions to discharge under low flow conditions (including under surficial ice) and stabilizes water temperatures under low and transitional flow conditions.

As these examples illustrate, the FEIS likely underestimates the impacts of groundwater pumping and processing demands, the extent of groundwater drawdown both within and across watersheds, and, thus, the influence these groundwater-related factors would have on downstream flow changes associated with the 2020 Mine Plan.

B.4 FEIS Assessment of Fish Habitat Changes

Assessment of streamflow and fish habitat changes under the 2020 Mine Plan are closely related, given the fish habitat assessment methods used in the FEIS. This section considers potential issues associated with how the FEIS evaluated fish habitat changes and how those issues affect conclusions about impacts of the 2020 Mine Plan. The issues raised here do not affect EPA's conclusion that the habitat losses (i.e., losses of anadromous fish streams, additional streams, and wetlands and other waters) or streamflow changes predicted to occur under the 2020 Mine Plan each constitute an unacceptable adverse effect on fishery areas. Rather, these issues highlight concerns that the FEIS evaluation of fish habitat changes did not represent an accurate and thorough assessment of likely impacts.

B.4.1 Overview of Fish Habitat Assessment Methods

The FEIS relied on the PHABSIM modeling approach, which is part of the Instream Flow Incremental Methodology developed by the U.S. Fish and Wildlife Service (Bovee et al. 1998) to model changes in fish habitat in response to changes in streamflow. In the FEIS fish habitat analysis, PHABSIM was used to predict effects of streamflow changes on the amount of available habitat for multiple fish species and life stages. There are two basic components of a PHABSIM model: (1) the hydraulic representation of the stream at a stream transect; and (2) the habitat simulations at a stream transect using defined hydraulic parameters (i.e., water depth and velocity and, for some life stages, substrate). Habitat suitability curves (HSCs) for different fish species and life stages are used to calculate weighted usable habitat area for a stream segment represented by the transect.

In addition, the HABSYN program developed by R2 Resource Consultants was used to expand the standard transect-based component of PHABSIM to unsampled habitat areas (USACE 2020: Appendix K4.24, PLP 2018b: RFI 048). To EPA's knowledge, the HABSYN model has never been validated or documented in the scientific literature. The basic premise of extending sampled transect data to unsampled habitats was not evaluated, but was assumed in the FEIS to be valid for assessing fish habitat in unsampled areas.

Together, PHABSIM and HABSYN models were used to estimate total acres of fish habitat—by species, life stage, and reach—for wet, average, and dry climate conditions during pre-mine (baseline), end-of-mine, and post-closure phases of mine development. The following sections focus on potential issues associated with the modeling of fish habitat changes under the 2020 Mine Plan, as reported in the FEIS (USACE 2020: Section 4.24, Appendix K4.24). Many of these issues were previously identified in EPA (2019) and National Marine Fisheries Service (NMFS) (2020).

B.4.2 Use of PHABSIM Models to Estimate Fish Habitat Changes

PHABSIM is a one-dimensional physical model that has been used for decades to model habitat and manage streamflows for fish populations, including salmon. Because PHABSIM is a method that does not have a direct relationship to fish population biology (Waddle 2001), it has several limitations that have long been acknowledged (e.g., Anderson et al. 2006, Railsback 2016) and should be addressed during application and considered in interpreting results when PHABSIM is used. The FEIS did not consider many of these issues in its fish habitat analysis; as a result, its estimates of changes to fish habitat resulting from the 2020 Mine Plan likely underestimate the extent of those changes. This section explores specific assumptions and limitations of how PHABSIM models were implemented in the FEIS (USACE 2020: Section 4.24, Appendix K4.24), as well as factors that were omitted from fish habitat analyses.

B.4.2.1 Assumption that Streamflow Equals Fish Habitat

The FEIS bases its conclusions about changes in the availability of fish habitat under the 2020 Mine Plan on PHABSIM modeling (USACE 2020: Section 4.24, Appendix K4.24), which, as implemented in the FEIS, assumes that water depth and velocity are the only determinants of fish habitat. This assumption cannot defensibly be made unless (1) field data and analysis show that water depth and velocity are related to fish habitat in the region, and (2) there is a comprehensive evaluation of the other factors determining fish habitat that would potentially be affected by the 2020 Mine Plan.

Importantly, the FEIS and its supporting documents did not establish that relationships between discharge (water depth and velocity) and fish habitat exist in the SFK, NFK, and UTC. This is of particular concern because these watersheds are groundwater-driven systems. When the assumption that habitat use primarily is structured by surface water hydraulics is not valid, hydraulic habitat modeling methods such as PHABSIM are not appropriate (Waddle 2001). Field data demonstrate that fish occurrence in areas of differing water depths and velocities changed with streamflow and over time (PLP 2011: Appendix 15.1C)—that is, a consistent relationship between water depth and velocity and fish habitat use was not observed. These data demonstrate variability in fish habitat use among survey years, an indication that the underlying PHABSIM assumptions are not valid.

The PHABSIM model used in the FEIS incorrectly assumed that habitat can be reduced to discharge. Even if this assumption were valid—as discussed above, it was not—the PHABSIM analysis also failed to account for or consider other ecologically relevant fish habitat parameters, such as groundwater exchange, substrate, water temperature, water chemistry, cover, and habitat complexity (e.g., wetlands and other off-channel habitats). While water depth and velocity are important determinants of fish habitat, they are only two variables interacting with a suite of other factors that determine overall fish habitat suitability.

PHABSIM models are not appropriate as the sole means to evaluate habitat for fish species that key into specific habitat variables unrelated to water depth and velocity. For example, the SFK, NFK, and UTC watersheds experience complex interactions between surface water and groundwater, with

repercussions for fish habitat. Spawning Sockeye Salmon (*Oncorhynchus nerka*) and Coho Salmon (*O. kisutch*) select habitats based on groundwater upwelling and downwelling, respectively. Changes in these habitat determinants were not reflected in the PHABSIM analysis; in general, the utility of PHABSIM approaches may be extremely limited in areas such as the SFK, NFK, and UTC watersheds, with extensive and complex surface water-groundwater interactions (NMFS 2020).

In addition, the PHABSIM analysis did not consider how disruption of surface water flows, groundwater pathways, and aquifer characteristics would alter water temperatures and thermal patterns within the SFK, NFK, and UTC watersheds. The alteration of water temperatures is a concern because fishes are at risk from disruption of the heterogeneity and spatial distribution of thermal patterns, which drive their metabolic energetics. Fish populations rely on groundwater-surface water connectivity, which has a strong influence on stream thermal regimes throughout the Nushagak and Kvichak River watersheds and provides a moderating influence against both summer and winter temperature extremes (Woody and Higman 2011). Coho Salmon may move considerable distances over short time periods in response to food resources and temperature to enhance growth and survival (Armstrong et al. 2013). The PHABSIM analysis also does not account for the benefits of complex stream features resulting from off-channel habitats (e.g., side channels, sloughs) or other habitats, such as islands or tributary junctions. These can be important features for fish populations: for example, tributary junctions are biological hotspots, and off-channel habitats are often the most important factors in salmonid distribution (e.g., Swales and Levings 1989, Benda et al. 2004).

By considering only water depth and velocity, the one-dimensional PHABSIM analysis simplifies and homogenizes the complexity of fish habitat into combinations of only water depth and velocity. This simplified approach provides only a coarse assessment of suitable fish habitat and predicted impacts resulting from the 2020 Mine Plan. As a result, this approach likely underestimates actual changes to fish habitat that would be likely to result from changes to the full suite of variables determining available fish habitat.

B.4.2.2 Data Collection Issues

The approach taken to develop valid fish-habitat associations typically involves mapping defined, representative, hierarchical habitats; conducting fish surveys at sites both used and unused by fish across the full seasonal distribution (i.e., spring, summer, fall, and winter) of all fish species and life stages (including incubation, emergence, and fry); and then selecting study sites for analysis (e.g., Rosenfeld 2003). Data collection efforts to support fish habitat modeling in the FEIS did not follow this approach and do not appear to be structured or consistently implemented to inform the PHABSIM model in a meaningful way. As a result, there are several issues of concern regarding the data used in the fish habitat analysis, in terms of both data-collection methods and data completeness; some examples are discussed below.

Additional environmental baseline data relevant to fish habitat use were collected, but these data were not used in the habitat impact analysis. Data on off-channel habitats are reported in PLP (2011, 2018a) (see Table 3-10) but were not used in analyses related to fish habitat. The SFK, NFK, and UTC were

modeled as single-channel systems in the PHABSIM analysis, despite the frequent occurrence of riparian wetland complexes, floodplains, beaver ponds, and other off-channel habitats throughout the area (Table 3-10; PLP 2011, 2018: Chapter 15). For example, up to 70 percent of the mainstem SFK downstream of Frying Pan Lake appears to be bordered by off-channel habitats (USACE 2020: Section 3.24). This complexity is not captured in the instream habitat classification, despite its prevalence and importance for different life stages of salmon (especially Coho Salmon) and other fish species.

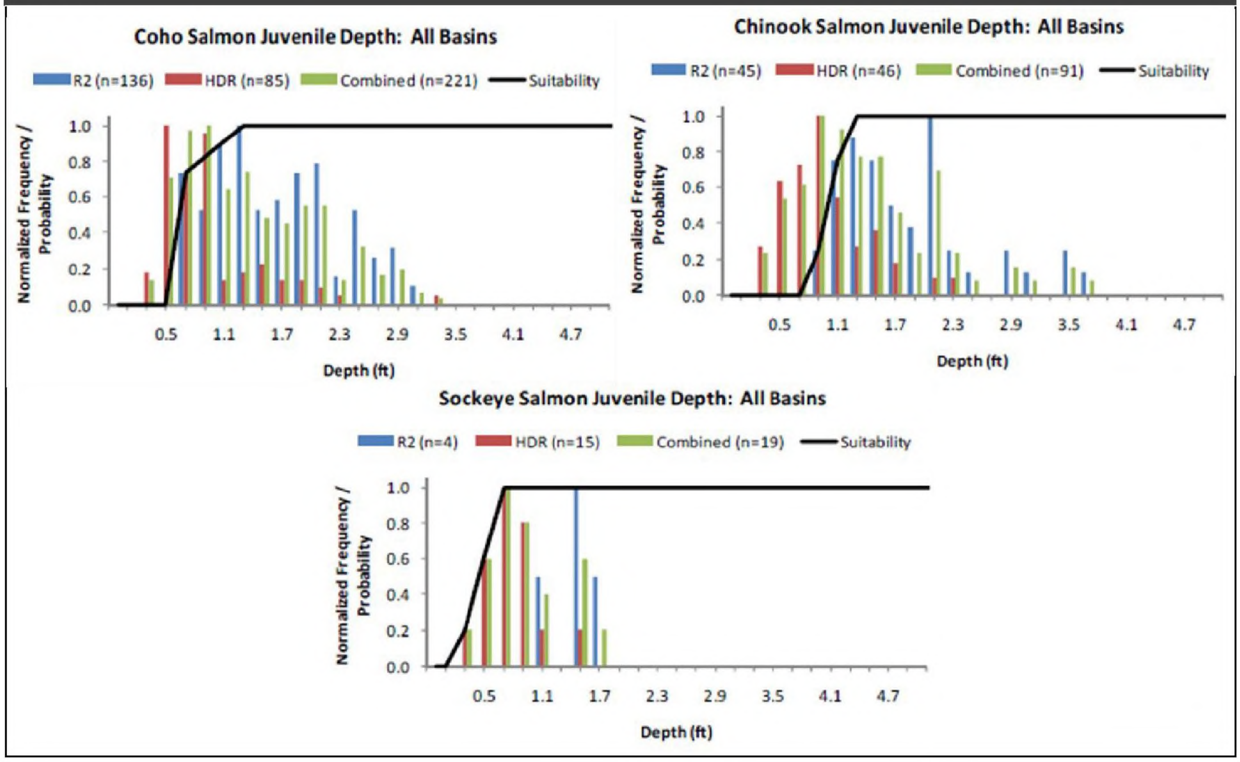
B.4.2.3 Habitat Suitability Curves

Biology is attempted to be incorporated into PHABSIM through the use of HSCs. The underlying premise of HSCs is that more fish will occur in more suitable habitats; thus, HSCs look at occurrence of a given fish species and life stage relative to a single habitat variable (e.g., water depth or velocity) (Naman et al. 2020). Generally speaking, the univariate nature of HSCs greatly oversimplifies the concept of habitat suitability for fishes (Section B.4.2.1). In addition, HSCs developed for evaluation of fish habitat impacts resulting from the 2020 Mine Plan do not reflect field data collected at the mine site (Figure B-2). PLP (2011: Appendix 15.1C) reported that the HSCs generally track the shape of the normalized observed data histograms, with the exception of maximum depth. However, they concluded that maximum depth is not a limiting factor for fish habitat use; thus, HSCs used in the fish habitat analysis do not include a descending limb for depth (Figure B-2). This is an indication that appropriate steps described by developers of PHABSIM and HSCs (Bovee 1986) were not taken to validate the ecological relevance of depth before applying a model that forces a relationship with depth.

The HSCs assume that more water means better fish habitat, and that fish will use deeper water if it is available. This assumption is problematic as applied in the FEIS, given that the field data actually demonstrate decreased habitat use by juvenile Coho, Sockeye, and Chinook (*O. tshawytscha*) salmon with increasing depth (Figure B-2). For example, Figure B-2 shows that as water depth increased above approximately 2.1 ft, the probability that juvenile Coho and Chinook salmon would be found decreased, with no juveniles of either species found at water depths above roughly 3.7 ft.

Railsback (2016) considers univariate HSCs obsolete and suggests that they introduce considerable error to habitat modeling. Modern multivariate resource selection models or HSCs based on bioenergetic models (which relate habitat conditions to net energy gain by fishes) can address some of these limitations and provide a better fit to observed fish habitat-use data (Naman et al. 2019, Naman et al. 2020). Particularly for drift-feeding fishes like salmonids, univariate HSCs may introduce systematic bias related to factors such as density-dependent territoriality and failure to consider water-velocity effects on prey availability (Rosenfeld and Naman 2021).

Figure B-2. Sample habitat suitability curves used in the PHABSIM fish habitat modeling. Models are for juvenile Coho, Chinook, and Sockeye salmon and water depth. From PLP 2011: Appendix 15.1C.



In addition, HSCs were not developed (or not included in the PHABSIM analysis) for all relevant life stages. For example, the fry life stage (salmonids less than 50 mm) was not included in the PHABSIM analysis; according to RFI 147, they were excluded because they occupy low velocity areas with cover and the "habitat needs of fry are generally met with flows much lower than those for other life stages" (PLP 2019e: RFI 147). This document also states that fry habitat generally is not limiting, although no support for this statement is provided (PLP 2019e: RFI 147). Hardy et al. (2006) discuss the importance of evaluating fry response to streamflow changes and present an approach for evaluating fry habitat availability. No HSCs were developed for the egg-incubation stage; in fact, impacts to the egg incubation stage were not considered in any assessment of impacts resulting from the 2020 Mine Plan. Early salmonid life stages (i.e., eggs and alevins) are particularly susceptible to adverse effects associated with changes in flow (Warren et al. 2015). Potential impacts to these life stages include scouring of redds and egg mortality with increased streamflows, freezing and desiccation with decreased streamflows, and loss of water-temperature buffering, waste removal, and aeration during the incubation stage due to changes in groundwater exchange. These early developmental stages are also when imprinting to natal waters begins; flow changes that alter the physical and chemical signatures of the water during these stages may impair imprinting and, thus, adult homing capabilities. Failure to evaluate impacts of the 2020 Mine Plan on these important life stages represents a significant omission in the FEIS.

B.4.3 Results and Conclusions of PHABSIM Modeling Related to Fish Habitat

The PHABSIM models used in the FEIS provide an oversimplification of fish habitat changes under the 2020 Mine Plan that does not account for the inherent complexity of aquatic habitats in the SFK, NFK, and UTC watersheds. As a result, the magnitude of fish habitat changes identified in the FEIS likely is an underestimate of actual effects of the project. However, even this underestimate represents an unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

Examples of specific issues related to FEIS conclusions about fish habitat changes associated with the 2020 Mine Plan are provided below.

- Based on PHABSIM flow modeling, Figure K4.24.1 (USACE 2020: Appendix K4.24) depicts that most habitat units would not decrease under the 2020 Mine Plan. Because this figure only includes information about mainstem channels and omits tributaries and off-channel habitats, it does not present a complete depiction of potential effects. Exclusion of these non-mainstem habitats—which are critical habitats for many fish species and life stages—from estimates of fish habitat changes under 2020 Mine Plan results in a significant underestimate of impacts.
- As detailed in Section B.3, adjacent mainstem reaches of the SFK are predicted to experience both large decreases (52 percent) and increases (110 percent) in average monthly streamflows in April. The FEIS did not assess changes to suitable fish habitat in these SFK reaches, despite their documented use by juvenile salmon. The portion of SFK Reach E above Frying Pan Lake (and stream gage SK100G) is specified as rearing habitat for Coho Salmon; Frying Pan Lake and portions of the SFK down to stream gage SK100F are used for rearing by both Coho and Sockeye salmon (USACE 2020: Section 3.24, Giefer and Graziano 2022).
- The FEIS states that treated discharges would be "optimized to benefit priority species and life stages for each month and stream" (USACE 2020: Section 4.24, Table 4.24-2). Specific details about how discharges would be managed and monitored are not provided, and EPA has concerns that the goal of habitat optimization would not come to fruition. These concerns are due in part to limitations of the flow-habitat model development and application, in addition to limitations of the planned streamflow monitoring program. The Monitoring Summary provided by PLP states that monitoring of surface-water flow and quality is proposed to be conducted downstream of water-discharge points on a quarterly basis and would focus on streamflow and fish presence surveys (PLP 2019e: RFI 135). Because streamflow monitoring is not described as being used for real-time WTP discharge decisions, the optimization approach appears to be pre-planned, based on numerous assumptions that would not reflect the natural hydrologic regime. The FEIS does not indicate that adaptive management would be applied to ensure that habitat optimization is achieved or consider how differences across species and life stages would result in adverse effects for species other than each month's priority species and life stage.

These and other issues support the contention that application of the PHABSIM flow-routing model to evaluate fish habitat changes under the 2020 Mine Plan is flawed for two key reasons: (1) it does not

consider habitat complexity, which is a critical component of the extremely complex aquatic system that exists in the SFK, NFK, and UTC watersheds; and (2) it does not integrate losses resulting from critical habitat components other than water depth and velocity, such as water temperature, groundwater interactions, and off-channel habitats. Cumulatively, the results of the analysis thus underestimate the project effects and its consequences for fish and fish habitat.

B.4.4 Summary

The fish habitat assessment included in the FEIS relies heavily on the PHABSIM modeling approach. Because the PHABSIM model only considers water depth and velocity and does not account for complex interactions between surface waters and groundwater, the FEIS necessarily provides an overly simplistic characterization of fish habitat. EPA (2019) and NMFS (2020) highlighted the value of conducting a comprehensive analysis of the suite of environmental drivers associated with distributions and abundances of the fish species and life stages found throughout the SFK, NFK, and UTC watersheds. The FEIS acknowledges that PHABSIM does not account for other factors affecting fish habitat and ultimately fish survival and that losses of headwater streams and wetlands and changes to streamflows, groundwater inputs, water chemistry, and water temperature would occur under the 2020 Mine Plan (USACE 2020: Appendix K4.24)—all of which are likely to affect fish habitat use, as well as other components of these aquatic resources. However, the integrated effect that these changes are predicted to have on fish habitat was not assessed adequately to conclude in the FEIS that there will be no effects on fish habitat, abundance, and productivity. The FEIS likely underestimates both direct and indirect effects on fish habitat under the 2020 Mine Plan, and its conclusion of no "measurable impact" on fish populations is not supported by the evidence, particularly at spatial scales relevant to the 2020 Mine Plan (i.e., the SFK, NFK, and UTC watersheds; see Section B.2.1). Even the underestimate of fish habitat changes resulting from the 2020 Mine Plan documented in the FEIS represents unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

B.5 Other Effects on Aquatic Resources

The prohibition and restriction included in this final determination focus on direct losses of aquatic habitats and losses of the ecological subsidies that these habitats provide to downstream waters (Sections 4.2.1 through 4.2.3), as well as additional secondary effects caused by streamflow alterations (Section 4.2.4). These impacts, as evaluated in the FEIS, would result in unacceptable adverse effects on fishery areas in the SFK, NFK, and UTC watersheds and are the basis for the prohibition and restriction detailed in Section 5. However, the impacts underpinning this prohibition and restriction are only a subset of the many ecological effects likely to result from implementation of the 2020 Mine Plan. This section considers other key impacts that development of the 2020 Mine Plan would have on aquatic habitats and fish populations in the SFK, NFK, and UTC.

B.5.1 Water Quality Effects

The FEIS states that adaptive management strategies would be employed at the WTPs to address water quality issues prior to discharging to the environment, including adding further treatment, as needed (USACE 2020: Section 4.18). However, the FEIS also acknowledges that "over the life of the mine, it is possible that [Alaska Pollutant Discharge Elimination System] permit conditions may be exceeded for various reasons (e.g., treatment process upset, record-keeping errors) as has happened at other Alaska mines" (USACE 2020: Page 4.18-13). It is likely that the predicted water quality of effluents is overly optimistic (Sobolewski 2020), further suggesting that water quality effects are underestimated in the FEIS.

Despite acknowledgement of the potential for water quality exceedances, Section 4.24 of the FEIS states that treated water discharges are expected to result in "no noticeable changes" in water chemistry and only slight increases in water temperature immediately below discharge points (USACE 2020). This misrepresents the information presented in the FEIS, which indicates that treated water discharges would substantially increase concentrations of 11 constituents (e.g., chloride, sulfate, calcium, magnesium, sodium, nitrate-N, ammonia, hardness) in receiving waters relative to baseline concentrations (USACE 2020: Section 4.18). For example, chloride loads in the NFK are predicted to increase by 1,620 percent (USACE 2020: Page 4.18-19); nitrate-nitrite and ammonia are predicted to be 30 times and 12 times higher than baseline concentrations, respectively (USACE 2020: Tables K3.18-7 and K4.18-13); total dissolved solids are predicted to be more than three times higher than baseline concentrations in UTC, and approximately 12 times higher than baseline concentrations in the NFK (USACE 2020: Tables K3.18-7, K3.18-9, and K4.18-13).

Section 4.18 of the FEIS does not identify environmental consequences from these predicted changes in water chemistry, and Section 4.24 of the FEIS suggests that there would be no impacts to fishes because point-source discharges are not expected to exceed water quality criteria. However, FEIS modeling indicates that discharges from WTP #1 during operations would exceed the standard for ammonia; it is also possible that the treated water discharges would result in seasonal exceedances of the turbidity standard (USACE 2020: Section 4.18). Furthermore, fishes and other aquatic organisms are adapted to the naturally occurring water chemistry in the SFK, NFK, and UTC headwaters, and the ambient concentrations of many water chemistry parameters in these systems are much lower than existing water quality criteria (O'Neal 2020). For this reason, water chemistry changes that do not exceed water quality criteria but that significantly alter natural conditions may adversely affect aquatic biota. For example, research has shown that low concentrations of copper can result in olfactory impairment in salmonids (e.g., McIntyre et al. 2012, Morris et al. 2019), with potential repercussions for homing abilities and predator avoidance.

In addition to water quality changes resulting from treated water releases, there is also the potential for accidents and spills to affect water quality. Although the FEIS acknowledges the potential for acute toxicity and sublethal effects on fish, conclusions regarding impacts to fishes from potential spills appear to be based on the potential for direct habitat loss. For example, regarding the modeled pyritic tailings

release scenario, the FEIS states that "[c]admium and molybdenum would remain at levels exceeding the most stringent [water quality criteria] as far downstream as the Nushagak River Estuary, approximately 230 miles downstream from the mine site" and "[t]hese metals would remain at elevated levels above WQC [water quality criteria] for several weeks..." (USACE 2020: Page 4.27-139). The FEIS concludes that:

> [t]he low-level use of the habitat that would be impacted (based on densities of juvenile Chinook and coho salmon captured in these habitats) and the low numbers of coho spawning near the confluence of Tributary SFK 1.240 with the SFK, indicates drainage-wide or generational impacts to populations of salmon from direct habitat losses associated with the scenario would not be expected" (USACE 2020: Page 4.27-144).

As discussed earlier, the FEIS does not appear to address impacts to aquatic resources from the elevated metal concentrations, which would also affect fish populations.

The proposed mine also would likely alter water chemistry via land runoff and fugitive dust, and the FEIS likely underestimates these impacts. For example, the volume of material that would potentially leach metals to the environment is likely underestimated due to the use of a non-conservative neutralization potential/acid-generating potential ratio to characterize materials (USACE 2020: Section 3.18), as well as the application of a large temperature correction that is not representative of field conditions (USACE 2020: Appendix K3.18). The modeling of impacts from fugitive dust underreports the area affected and does not account for watershed loading or the effects of seasonal flushes to surface waters, such as during snowmelt (USACE 2020: Appendix K4.18). Watershed loading and "first flush" effects are also relevant to the transport of leached metals to surface waters. The FEIS also does not take into consideration the likely effect of sulfate loading from the treated water discharges on mercury methylation and subsequent bioaccumulation in fish and other aquatic organisms.

In addition to changes in water chemistry, the proposed mine would significantly alter water temperature. The FEIS predicts water temperatures will change by -1.6 to +2.8 degrees Celsius (°C) in the SFK, NFK, and UTC watersheds, from approximately 0.5 to 2.75 miles downstream of WTP discharge sites (USACE 2020: Section 4.18, Table 4.24-3). Proposed WTP discharge volumes are greatest in the NFK, which is also where the greatest temperature changes are predicted to occur. Summer water temperatures could be warmer or cooler (by approximately -1.6 to +1.6 °C), but during winter water temperatures would increase (by approximately +1.2 to +2.8 °C) (USACE 2020: Table 4.24-3).

The threshold between completely frozen and partially frozen streams can be a narrow one (Irons et al. 1989), especially for small streams with low winter groundwater inputs (i.e., like many of the headwater streams in the SFK, NFK, and UTC watersheds). As a result, even small increases in winter water temperatures can have large effects. These predicted increases in winter streamflow and temperature would likely reduce ice cover and increase flow velocities, resulting in substantial alteration of fish habitats (Huusko et al. 2007, Brown et al. 2011) and reduced spawning success due to the scouring of redds.

The influence of temperature on fish bioenergetics is well understood (Brannon 1987, Beacham and Murray 1990, Hendry et al. 1998, Quinn 2018), and even small increases in water temperature can affect

salmon development, growth, and timing of life-history events such as emergence and migration (Section 4.2.4.5) (e.g., Beacham and Murray 1990, McCullough 1999, Fuhrman et al. 2018, Adelfio et al. 2019, Sparks et al. 2019). The FEIS acknowledges the potential for impacts to eggs and alevins in spawning gravels due to adverse effects on egg development, hatching, and emergence timing (USACE 2020: Page 4.24-23). For example, increases in water temperatures during alevin development can increase development rates and associated yolk conversion rates (USACE 2020: Page 4.24-23), potentially leading to faster yolk depletion and earlier emergence from the gravel at overall smaller sizes (Weber-Scannell 1991). The timing of egg hatching and fry emergence is critical for survival, and fry that emerge too early could experience reduced feeding, growth, and survival due to mismatches in the timing of prey availability or increased predation on smaller-sized fry at emergence (Rooke et al. 2019). Altered water temperatures resulting from the loss of groundwater inputs also would likely change the species composition and richness of macroinvertebrates, a key food for juvenile salmonids, and alter overall macroinvertebrate abundance and productivity in the affected reaches (e.g., Campbell et al. 2020).

Water quality in the SFK, NFK, and UTC are predicted to change downstream of the mine site under the 2020 Mine Plan, due to the loss of upstream aquatic habitats, changes in surface water and groundwater flows, and the release of treated water discharges. These changes would create water quality conditions that would differ from the current baseline conditions to which fish communities (as well as other organisms) in the region are adapted. These changes would alter fish habitat and the ecological cues that influence the timing of fish migration, spawning, incubation, emergence, rearing, and outmigration with likely negative consequences. Because the FEIS does not consider these effects, it further underestimates potential impacts of the 2020 Mine Plan to the region's aquatic resources.

B.5.2 Multiple, Cumulative Effects

Under the 2020 Mine Plan, aquatic resources in the SFK, NFK, and UTC watersheds would experience a suite of co-occurring and interacting changes, including losses of headwater streams and wetlands; changes in streamflow regime due to changes in surface water and groundwater hydrology and treated water discharges; and changes in water temperature and water chemistry. However, the FEIS estimates effects of the 2020 Mine Plan by considering each impact independently—that is, by assuming each effect would act in isolation, typically without consideration of how multiple effects acting simultaneously would impact aquatic resources. Even considered in isolation, impacts on aquatic habitats documented in the FEIS constitute an unacceptable adverse effect on fishery areas (Section 4.2); a more holistic evaluation of how the full suite of changes expected to result from the 2020 Mine Plan would likely only increase the extent and magnitude of these impacts. This failure to consider multiple, cumulative effects is evident across multiple contexts, as the following examples below demonstrate.

- Effects on species, and life stages within species, are considered independently. There is no consideration of how "optimization" of water discharges for priority species and life stages at certain times of year would affect other species and life stages (USACE 2020: Section 4.24).

Similarly, there is no consideration of how the direct effects of the 2020 Mine Plan on one life stage within a species will indirectly influence subsequent life stages (Marra et al. 2015), in addition to any direct effects those life stages experience.

- Effects on fishes are considered only in terms of changes to fish habitat, despite that fact that fishes also will be affected by impacts on lower trophic levels (e.g., macroinvertebrates, algae), which may be particularly sensitive to changes in physical and chemical characteristics likely to occur under the 2020 Mine Plan.
- Effects in different sections of the stream channel are considered independently, without consideration of how changes in upstream portions may influence effects in downstream portions and vice versa (e.g., by affecting upstream movement).
- Effects of different stressors (e.g., changes in flow, temperature, water quality, and sedimentation) are considered independently, without consideration of how simultaneous exposure to multiple stressors, which also affect each other, would alter aquatic resources.

As a result, the FEIS likely underestimates how multiple, co-occurring changes associated with the 2020 Mine Plan would cumulatively affect the region's aquatic habitats and fish populations. Although all aquatic resources in and downstream of the mine site would be affected by a suite of co-occurring (and likely interacting) changes to chemical, physical, and biological conditions (Hodgson et al. 2019), the impact of each change is only evaluated as if it would be acting in isolation. The impacts reported in the FEIS likely represent a minimum estimate of how aquatic resources would be affected under the 2020 Mine Plan. This underestimation of cumulative impacts compounds the numerous underestimates of single-factor impacts throughout the FEIS. For example, based only on modeled streamflow impacts, RFI 149 concludes that there would be a loss of more than 10 percent of Chinook Salmon spawning habitat in the Koktuli River (PLP 2019f: RFI 149), a major producer of Chinook Salmon within the Nushagak River and within the state of Alaska. For reasons discussed in Sections B.3 and B.4, this value likely underestimates streamflow impacts to Chinook Salmon populations; this value also fails to account for other co-occurring contributors to Chinook Salmon population impacts that would result from the 2020 Mine Plan, such as changes in water temperature, water chemistry, and downstream transport of energy and materials from headwater streams and wetlands.

B.6 Climate Change and Potential Mine Impacts to Aquatic Habitats and Fish

The ecosystems that support Pacific salmon species, in Alaska and elsewhere, are experiencing rapid changes due to a changing climate (Markon et al. 2018, Jones et al. 2020, von Biela et al. 2022). Alaska is warming faster than any other state (Markon et al. 2018). Across the entire Bristol Bay watershed, average temperature is projected to increase by approximately 4°C by the end of the century, with winter temperatures projected to experience the highest increases (EPA 2014: Table 3-5, Figure 3-16). Similar patterns are projected in the Nushagak and Kvichak River watersheds (EPA 2014: Table 3-5). By

the end of the century, precipitation is projected to increase roughly 30 percent across the Bristol Bay watershed, for a total increase of approximately 250 mm annually (EPA 2014: Table 3-6, Figure 3-17). In the Nushagak and Kvichak River watersheds, precipitation is projected to increase roughly 30 percent as well, for a total increase of approximately 270 mm of precipitation annually (EPA 2014: Table 3-6). At both spatial scales, increases in precipitation are expected to occur in all four seasons (EPA 2014: Table 3-6). Based on evapotranspiration calculations (i.e., calculations of the total amount of water moving from the land surface to the atmosphere via evaporation and transpiration), annual water surpluses of 144 mm and 165 mm are projected for the Bristol Bay watershed and the Nushagak and Kvichak River watersheds, respectively (EPA 2014: Table 3-7, Figure 3-18).

These projected changes in temperature and precipitation are likely to have repercussions for both water management at the proposed mine and the surrounding aquatic resources. For example, increases in air temperature are likely to affect evapotranspiration and exacerbate thermal stress, increasing the probability of high severity wildfires (Lader et al. 2017). The combined effects of increased air temperature, altered timing and type of precipitation, and vegetation changes likely will lead to altered stream temperature regimes, with implications for fish metabolism and timing of key life history events. For example, if water temperatures increase and cold-water species cannot find optimal conditions of groundwater exchange, incubating eggs may fail to develop or develop too rapidly. In precipitation driven streams, Adelfio et al. (2019) reported shifts in modeled incubation timing by Coho Salmon by up to 3 months during years with warmer winters. Given that substantially warmer winters are projected to be increasingly common in Alaska in the near future (Lader et al. 2017), these life history shifts may become increasingly common. Such shifts in timing can result in egg emergence that is out of sync with the availability of food resources (Cushing 1990, McCracken 2021), as well as other asynchronizations across salmon life histories. These life history shifts may disrupt the adaptation of salmon life stages to local environmental conditions, particularly if altered timing of key life history events such as emergence, migration, or seasonal movements is no longer synched to favorable conditions for salmonid growth and survival. These changes can lead to adverse impacts on resilience of Pacific salmon populations (Crozier et al. 2008).

Such increases in temperature (and associated adverse ecological effects) can occur during the winter, and at temperatures well below the State of Alaska's critical temperature threshold for spawning or egg incubation (13°C; ADEC 2020). Thermal effects on fry size and emergence timing can interact with streamflow to adversely affect juvenile salmon survival. Increases in precipitation, as well as changes in the seasonality of precipitation, snowpack, and the timing of snowmelt, would likely affect streamflow regimes. High-intensity rainfalls, projected to increase in frequency with climate change (Lader et al. 2017), may contribute to increased scouring and sedimentation of stream channels. Increased exposure to earlier or larger peak streamflows can displace incubating eggs or newly emerged salmon fry, contributing to mortality. Stream types at the mine site are highly susceptible to scour and erosion and could be destabilized significantly by streamflow or sediment regime changes (Brekken et al. 2022).

Wobus et al. (2015) incorporated climate change scenarios into an integrated hydrologic model for the upper Nushagak and Kvichak River watersheds. These simulations projected changes in water

temperature, average winter streamflows, and dates of peak streamflows by 2100 (Wobus et al. 2015). Ultimately, these projected increases in temperature and changes in hydrology could affect salmon populations in multiple ways, such as alteration of spawning and rearing habitats, changes in fry emergence and growth patterns, and direct thermal stress (Tang et al. 1987, Beer and Anderson 2001, Bryant 2009, Wobus et al. 2015).

Despite these expected climate changes in the Bristol Bay region, many of the models used in the FEIS to evaluate potential impacts of the 2020 Mine Plan were parameterized based on past environmental conditions. For example, the mine site water-balance model included in the FEIS incorporated climate variability by using the 76-year average monthly synthetic temperature and precipitation record (USACE 2020: Section 3.16). EPA (2019) recommended that the FEIS consider how projected changes in the type (e.g., snow versus rain) and timing of precipitation could affect impacts to aquatic resources under the 2020 Mine Plan, but no future climate scenarios were included in the FEIS analysis of streamflow changes under the 2020 Mine Plan. It is not clear that past variability in temperature and precipitation will adequately capture future variability. Schindler and Hilborn (2015) stated that "…we should expect that the future is not likely to be a simple extrapolation of the recent past." Predictions of future habitat based on conditions in the recent past—or even current conditions—are of limited utility (Moore and Schindler 2022). As a result, models like those used in the FEIS may fail to adequately characterize mine impacts in ecosystems experiencing an altered future climate (Sergeant et al. 2022).

A thorough evaluation of potential impacts under the 2020 Mine Plan should consider future climate scenarios, particularly in terms of water treatment and management and potential effects on aquatic habitats and salmon populations. Even without this evaluation, the impacts on aquatic habitats documented in the FEIS constitute an unacceptable adverse effect on fishery areas (Section 4.2); consideration of how future climate conditions would affect these impacts would not change this unacceptability finding, but would give a more complete assessment of likely effects associated with the 2020 Mine Plan. A key feature of salmon populations in the Bristol Bay watershed is their genetic and life history diversity (i.e., the portfolio effect), which serves as an overall buffer for the entire population (Section 3.3.3). Different sub-populations may be more productive in different years, which affords the entire population stability under variable conditions year to year. If this variability increases over time due to changes in temperature and precipitation patterns, this portfolio effect becomes increasingly important in providing the genetic diversity to potentially allow for adaptation; thus, affecting or destroying genetically diverse populations may have a larger than expected effect on the overall Bristol Bay fishery under future climate conditions.

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Attachment 1

How Certain FEIS Conclusions Relate to EPA's Final Determination

A few commenters on the proposed determination cited specific conclusions in USACE's 2020 FEIS (USACE 2020a) as potentially contradicting EPA's conclusions in the final determination. In this attachment, EPA provides the FEIS conclusions (verbatim, as cited by commenters) and details why these FEIS conclusions do not contradict the conclusions underpinning EPA's final determination.

The FEIS conclusions highlighted in these comments are grouped into six general themes: (1) that the 2020 Mine Plan is expected to have no "measurable" effect on fish populations or fisheries; (2) that the appropriate scale for analyzing potential effects is at the scale of the Bristol Bay, Nushagak River, and/or Kvichak River watersheds; (3) that expected effects of the 2020 Mine Plan would not exceed the natural range of variability in the system; (4) that habitat availability is expected to increase as a result of the 2020 Mine Plan; (5) that cumulative impacts of the 2020 Mine Plan will be minimal to moderate; and (6) that mining and fisheries successfully coexist in other watersheds. Note that these themes are not discrete categories, as many of the FEIS conclusions relate to multiple themes.

1. Conclusions related to "no measurable" changes, effects, or impacts of the 2020 Mine Plan

Commenters cited several FEIS quotes stating that the mine proposed to be developed under the 2020 Mine Plan is not expected to have a "measurable" effect or impact on fish populations.

Cited FEIS Quotes

1.a "The loss of habitat is not expected to have a measurable impact on fish populations based on physical habitat characteristics and fish density estimates in the affected reaches." [USACE 2020a: Page 4.24-1]

1.b "Measurable changes to fish populations in the Nushagak watershed are not expected to occur from changes in stream productivity based on the extent and magnitude of changes in stream productivity." [USACE 2020a: Page 4.24-21]

1.c "This impact is expected to be limited to the habitats within this reach and would not be expected to have a measurable effect on Bristol Bay salmon populations due to the magnitude and extent of the effect." [USACE 2020a: Page 4.24-24]

1.d "Impacts to Bristol Bay salmon are not expected to be measurable and given the vast breadth and diversity of habitat (and salmon populations) in the Bristol Bay watershed, impacts on the Portfolio Effect are certain but not likely to be noticeable in context of the Bristol Bay watershed." [USACE 2020a: Page 4.24-47]

1.e "The duration of direct impacts of the removal of anadromous habitat would be permanent. However, considering the physical characteristics and current fish use of habitat to be removed,

the consequently low densities of juvenile Chinook and coho observed in the affected tributaries, and the few numbers of spawning coho observed (see Section 3.24, Fish Values), impacts to anadromous and resident fish populations from these direct habitat losses would not be measurable, and would be expected to fall within the range of natural variability." [USACE 2020a: Page 4.24-46]

1.f "Alternative 1a would not have measurable effects on the number of adult salmon returning to the Kvichak and Nushagak river systems as a result of project construction and operations, due the limited lineal footage of upper Koktuli River fish habitat affected by placement of fill." [USACE 2020a: Page 4.6-9]

1.g "This alternative would not be expected to have measurable effects on the number of adult salmon, and therefore would have no impact to commercial fisheries." [USACE 2020a: Page 4.6-4]

1.h "There would be no measurable change in the number of returning salmon and the historical relationship between ex-vessel values and wholesale values. In addition, there would be no changes to wholesale values or processor operations expected for Alternative 1a. Under normal operations, the Alternatives would not be expected to have a measurable effect on fish numbers and result in long-term changes to the health of the commercial fisheries in Bristol Bay." [USACE 2020a: Executive Summary Page 87]

1.i "As with Alternative 1a, Alternative 3 would not be expected to measurably affect the health or value of Bristol Bay salmon fishery, including permit holder earnings, permit holder value, crew earnings, fishery first wholesale values, processor earnings, or local fiscal contributions." [USACE 2020a: Page 4.6-18]

1.j "Overall, impacts to fish and wildlife would not be expected to impact harvest levels. Resources would continue to be available because no population-level decrease in resources would be anticipated." [USACE 2020a: Executive Summary Page 51]

1.k "The Portfolio Effect is an observation that the Bristol Bay salmon run is produced from an abundance of diverse aquatic habitat; this diversity allows for a harvestable surplus even when some systems experience low abundance (Schindler et al. 2010). The term "Portfolio Effect" is taken from the concept of investment portfolios, where adding to the diversity of investments is thought to reduce risk (or the likelihood of occurrence of losses to the overall investment portfolio, even if some individual investments do not do well). Any loss of salmon production would have an effect on the Bristol Bay "portfolio," similar to the way that financial losses by individual investments would have an effect on an investor's portfolio. In this EIS, the effect to the Bristol Bay portfolio is considered by evaluating the amount of habitat and salmon production that would be lost. No long-term measurable changes in the number of returning salmon are expected, nor is genetic diversity expected to change; therefore, the impact to the Portfolio Effect would not be discernable." [USACE 2020a: Page 4.24-47]

EPA Response

As explained in detail below, none of the FEIS conclusions quoted above contradict EPA's conclusions in the final determination. In addition, numerous experts, including those from EPA, U.S. Fish and Wildlife Service, NMFS, tribes, and academia, have noted the limitations of the baseline environmental data underpinning certain analyses in the FEIS (e.g., O'Neal 2012, Parasiewicz 2012, Stratus Consulting 2012, Woody 2012, EPA 2019)[1] and criticized both the streamflow and fish habitat modeling upon which the FEIS conclusions about fishery impacts are based (e.g., EPA 2019, Lubetkin and Reeves 2020, NMFS 2020, Reeves 2020, Reeves and Lubetkin 2020, Wobus and Prucha 2020).[2] As a result, the FEIS conclusions about the lack of effects on fish habitats and fish populations often are not supported by the available evidence or are stated without acknowledgement and evaluation of the limitations and uncertainties inherent in the analyses presented to support those conclusions. FEIS values likely represent a minimum estimate of impacts to fishery areas in the SFK, NFK, and UTC watersheds—and as discussed in Section 4 of the final determination, even these minimum estimates represent an unacceptable adverse effect.

There are several reasons that the FEIS quotes cited above to do not contradict EPA's conclusions in the final determination:

- Most, if not all, of the above FEIS conclusions either explicitly or implicitly focus on impacts to fish populations at large spatial scales (e.g., the entire Bristol Bay watershed or the entire Nushagak River watershed). As discussed in greater detail below, this larger scale is not the only or the most appropriate scale at which to assess whether adverse effects will occur (see *2. Conclusions related to scales at which effects or impacts should evaluated*). EPA has not made an unacceptable adverse effects determination at these larger scales. EPA has determined that the impacts from the discharge of dredged or fill material evaluated in the final determination will result in unacceptable adverse effects on fishery areas at the scale of the SFK, NFK, and UTC watersheds. This scale is consistent with both the scale at which the FEIS analyzed effects resulting from the construction and operation of the 2020 Mine Plan (although the results of those analyses often were presented in terms of larger spatial scales), as well as the scale at which USACE based its decision to deny the permit application for the 2020 Mine Plan (USACE 2020b).

- Similarly, the final determination does not conclude that impacts to the fish-related endpoints mentioned in the quoted passages above—e.g., "adult salmon returning to the Kvichak and Nushagak river systems," "returning salmon," "harvest levels," "health or value of the Bristol Bay fishery"—will be measurable. Rather, EPA has determined that the impacts from the discharge of

[1] EPA recognizes that the SFK, NFK, and UTC are relatively well-sampled streams, compared with other streams in the region, due to PLP's efforts to collect environmental baseline data in areas draining the Pebble deposit area; however, these data are still spatially and temporally limited and thus should be interpreted with caution (see Sections B.1 and B.2 for more detail).

[2] Multiple professional societies expressed explicit support for EPA's findings and the proposed determination, including the world's foremost society of professional fisheries biologists, the American Fisheries Society (AFS 2022), and the National Association of Wetland Managers (NAWM 2022).

dredged or fill material evaluated in the final determination will result in unacceptable adverse effects on *fishery areas*, as referenced in Section 404(c) of the Clean Water Act (CWA) (33 U.S.C. § 1344). The FEIS clearly documents "measurable" impacts to these fishery areas from the discharge of dredged or fill material associated with construction and operation of the 2020 Mine Plan, for example:

  - "Mine site development would permanently remove approximately 22 miles of fish habitat in the North Fork Koktuli and South Fork Koktuli drainages." [USACE 2020a: Page 4-24.1]
  - "The magnitude, duration, and extent of aquatic habitat loss from development of the mine site would be the removal of 99.7 miles of streambed habitat and 125 acres of riverine wetland habitat." [USACE 2020a: Page 4.24-8].
  - "The mine site would eliminate 21 miles of fish habitat in the Koktuli River watershed, 8.5 miles of which is anadromous habitat." [USACE 2020a: Page 4.24-9)]

- The FEIS indicates that the 2020 Mine Plan would result in large-scale, permanent impacts to aquatic resources at the mine site, in terms of losses of anadromous streams, losses of additional streams that support anadromous streams, losses of wetlands and other waters that support anadromous streams, and changes in streamflow in anadromous streams downstream of the mine site. The final determination is based on EPA's evaluation of these "measurable" impacts that the FEIS concludes will occur during construction and operation of the mine. For example, the FEIS states that "impacts to wetlands and other waters would be certain if the project is permitted and constructed" (USACE 2020a: Page 4.22-5), that "the duration of impacts to surface water hydrology would vary from temporary to permanent" (USACE 2020a: Page 4.16-2), and that "the extent of the impact on the NFK and SFK rivers may extend to just below the confluence of the two rivers" (USACE 2020a: Page 4.16-2). Section 3 and Appendix B of the final determination discuss the importance of the aquatic resources that would be impacted in detail. The factual record strongly supports EPA's conclusion that the aquatic resources that would be lost or damaged at the mine site (1) are productive habitats for aquatic biota, including anadromous fishes, and (2) support the productivity of downstream anadromous waters. The functional and productive capacity of the lost fishery areas would be zero, because they would no longer provide fish habitat. The functional and productive capacity of remaining downstream fishery areas also would be significantly degraded due to the loss of inputs from the lost upstream aquatic resources.

- As detailed in Section B.1.1, FEIS conclusions that the loss of stream habitats expected to result from the construction and operation of the 2020 Mine Plan would be inconsequential for fish populations appear to be based on an assumption that the relative quality of these habitats is low and that these habitats have minimal influence on downstream waters. These assumptions and, thus, the conclusions based on them are not supported by the available information about these habitats or the current science surrounding the importance of headwater systems (see Section B.1.1 for additional discussion related to this point).

- As detailed in Section 4 and Appendix B of the final determination, available evidence indicates that the levels of impacts to fishery areas documented in the FEIS would adversely affect fish habitats and populations in the SFK, NFK, and UTC watersheds, the spatial scale to which EPA's final determination applies. Indeed, even the FEIS concludes that "…impacts on the Portfolio Effect are certain…" (quote 1.d). The levels of adverse effects on aquatic resources in the SFK, NFK, and UTC watersheds associated with the construction and operation of the 2020 Mine Plan, as identified in the FEIS, lead to the finding in the Record of Decision (ROD) that mine site impacts would cause significant degradation and, thus, cannot be authorized under the CWA (USACE 2020b)—a finding that is consistent with EPA's final determination.

- The FEIS concludes that impacts on the Portfolio Effect "would not be discernable" (quote 1.k) and "are not likely to be noticeable in context of the Bristol Bay watershed" (quote 1.d), "…nor is genetic diversity expected to change…" (quote 1.k), but the FEIS provides no evidence to support these conclusions (e.g., genetic evaluation of anadromous fishes captured at sites in the SFK and NFK watersheds). Moreover, the FEIS acknowledges that "…impacts on the Portfolio Effect are certain…" (quote 1.d) and the ROD concludes that construction and operation of the 2020 Mine Plan "may have a local portfolio effect" (USACE 2020b: Page B3-21). As detailed in Section 3.3.3 of the final determination, available evidence indicates that the high genetic diversity of anadromous fish populations in this region, at relatively fine spatial scales, depends on the diversity and complexity of high-quality, intact, and connected aquatic habitats.

- Certain FEIS conclusions cited by commenters have been taken out of context or are referring to aspects of the project that are not relevant to EPA's action. For example, quote 1.g is referring to effects of the transportation corridor, which is not considered in EPA's final determination.

2. Conclusions related to the scale at which impacts or effects should be evaluated

Commenters cited several FEIS quotes that relate to the scale or scales at which impacts or effects should be evaluated. Many of the FEIS conclusions finding no "measurable" impact or effect from the construction and operation of the 2020 Mine Plan depend explicitly or implicitly on the choice of scale—that is, whether impacts or effects are presented in terms of relatively large spatial scales (i.e., the Bristol Bay, Nushagak River, and/or Kvichak River watersheds) or in terms of smaller spatial scales directly relevant to where mining would occur (i.e., the SFK, NFK, and/or UTC watersheds).

Cited FEIS Quotes

2.a "The mine site area is not connected to the Togiak, Ugashik, Naknek, and Egegik watersheds and is not expected to affect fish populations or harvests from these watersheds." [USACE 2020a: Page 4.6-4]

2.b "Impacts to Bristol Bay salmon are not expected to be measurable and given the vast breadth and diversity of habitat (and salmon populations) in the Bristol Bay watershed, impacts on the

Portfolio Effect are certain but not likely to be noticeable in context of the Bristol Bay watershed." [USACE 2020a: Page 4.24-47]

2.c "Alternative 1a would not have measurable effects on the number of adult salmon returning to the Kvichak and Nushagak river systems as a result of project construction and operations, due the limited lineal footage of upper Koktuli River fish habitat affected by placement of fill." [USACE 2020a: Page 4.6-9]

2.d "As with Alternative 1a, Alternative 3 would not be expected to measurably affect the health or value of Bristol Bay salmon fishery, including permit holder earnings, permit holder value, crew earnings, fishery first wholesale values, processor earnings, or local fiscal contributions." [USACE 2020a: Page 4.6-18]

2.e "Impacts to Bristol Bay salmon are not expected to be measurable and given the vast breadth and diversity of habitat (and salmon populations) in the Bristol Bay watershed, impacts on the Portfolio Effect are certain but not likely to be noticeable in context of the Bristol Bay watershed." [USACE 2020a: Page 4.24-47]

2.f "Overall, impacts to fish and wildlife would not be expected to impact harvest levels. Resources would continue to be available because no population-level decrease in resources would be anticipated." [USACE 2020a: Executive Summary Page 51]

2.g "The Portfolio Effect is an observation that the Bristol Bay salmon run is produced from an abundance of diverse aquatic habitat; this diversity allows for a harvestable surplus even when some systems experience low abundance (Schindler et al. 2010). The term "Portfolio Effect" is taken from the concept of investment portfolios, where adding to the diversity of investments is thought to reduce risk (or the likelihood of occurrence of losses to the overall investment portfolio, even if some individual investments do not do well). Any loss of salmon production would have an effect on the Bristol Bay "portfolio," similar to the way that financial losses by individual investments would have an effect on an investor's portfolio. In this EIS, the effect to the Bristol Bay portfolio is considered by evaluating the amount of habitat and salmon production that would be lost. No long-term measurable changes in the number of returning salmon are expected, nor is genetic diversity expected to change; therefore, the impact to the Portfolio Effect would not be discernable." [USACE 2020a: Page 4.24-47]

EPA Response

As discussed in detail in Section B.2.1, the assessment of whether "measurable" impacts or effects occur is scale dependent. If an assessment considers a large-enough spatial scale, relative to the assessed area, when evaluating impacts or effects, the relative magnitude of those impacts or effects will diminish as a function of increasing scale (although their absolute magnitude remains unchanged). FEIS statements that there will be no "measurable" effect on fish populations are typically made at the scale of the entire Bristol Bay watershed, without an evaluation of effects at smaller spatial scales. Assessment of effects should occur at the spatial and temporal scales that are most relevant to the resources being evaluated. As such, an assessment of effects of developing a mine at the Pebble deposit should include conclusions

at the spatial and temporal scales that are most biologically relevant to the species (salmon) and life stages (eggs, juveniles, adults) of concern—that is, the spatial and temporal scales that ultimately determine the reproductive success and long-term persistence of these species and their genetically distinct populations.

EPA's final determination considers impacts at the scale of the SFK, NFK, and UTC watersheds because these watersheds are the areas that would be most directly affected by mine development at the Pebble deposit and because the most extensive physical, chemical, and biological data currently available have been collected in these watersheds (e.g., PLP 2011, PLP 2018a, USACE 2020a). Streams and wetlands in each of the SFK, NFK, and UTC watersheds provide habitat for five species of Pacific salmon and numerous other fish species, including genetically distinct populations. Each of these headwater watersheds also supports fish habitats and populations in larger downstream systems via contributions of water, organisms, organic matter, and other resources.

EPA has determined that the impacts from the discharge of dredged or fill material evaluated in the final determination will result in unacceptable adverse effects on fishery areas at the scale of the SFK, NFK, and UTC watersheds (see Section 4). EPA has not made an unacceptable adverse effects determination for the entire Bristol Bay watershed or for the entire Nushagak River watershed, or in the Togiak, Ugashik, Naknek, and Egegik watersheds.[3] The scale used by EPA is consistent with both the scale at which the FEIS analyzed effects resulting from the construction and operation of the 2020 Mine Plan and the scale at which USACE based its decision to deny the permit application for the 2020 Mine Plan (USACE 2020b). FEIS conclusions based on larger spatial scales do not invalidate conclusions made by EPA or USACE (USACE 2020b) at smaller spatial scales.

A key contention of the FEIS, in considering effects at larger spatial scales, is that there is an abundance of aquatic resources throughout the Bristol Bay watershed that will compensate for any impacts to aquatic resources from construction and operation of the 2020 Mine Plan (e.g., quote 2.b). As explained above and in Section B.2.1, this contention does not invalidate conclusions made regarding lost habitats at smaller, more relevant spatial scales. This concept also does not recognize that habitats are not interchangeable across these different scales. Discharges of dredged or fill material associated with the construction and operation of the 2020 Mine Plan will result in the loss of anadromous fishery areas in the headwaters of the NFK and SFK watersheds. Salmon that are adapted to and currently spawn and rear in these headwater habitats will not by default be able to successfully spawn and rear in other watersheds draining to Bristol Bay, as they will not be well adapted to conditions in these other areas and likely will be outcompeted by salmon that are. Similarly, the presence of existing downstream habitat does not negate the loss of headwater tributaries. As detailed in Box 3-1, the habitats that would

[3] Although EPA has not made an unacceptable adverse effects determination at these larger spatial scales, EPA recognizes that the SFK, NFK, and UTC watersheds are headwaters of the larger Bristol Bay watershed and the aquatic resources of the SFK, NFK, and UTC watersheds are connected to downstream aquatic resources in the larger Bristol Bay watershed. Thus, the intact headwater-to-larger river systems found in the SFK, NFK, and UTC watersheds, with their associated streams, wetlands, lakes, and ponds, help sustain the overall productivity of fishery areas in the larger Bristol Bay watershed.

be lost or damaged as a result of the discharge of dredged or fill material associated with construction and operation of the 2020 Mine Plan represent unique combinations of habitat characteristics and arrangements to which local populations of anadromous (and other) fishes are adapted. These habitats are not simply duplicates of other habitats within the Bristol Bay watershed.

3. Conclusions related to the impacts or effects of the 2020 Mine Plan falling "within the range of natural variability"

Commenters cited several FEIS quotes suggesting that any changes in aquatic resources resulting from the 2020 Mine Plan would have minimal effects because they would fall "within the range of natural variability" for these resources.

Cited FEIS Quotes

3.a "The duration of direct impacts of the removal of anadromous habitat would be permanent. However, considering the physical characteristics and current fish use of habitat to be removed, the consequently low densities of juvenile Chinook and coho observed in the affected tributaries, and the few numbers of spawning coho observed (see Section 3.24, Fish Values), impacts to anadromous and resident fish populations from these direct habitat losses would not be measurable, and would be expected to fall within the range of natural variability." [USACE 2020a: Page 4.24-46]

3.b "Therefore, the intensity of the impacts to surface water resources would be generally expected to result in changes in water quantity, likely within the limits of historic and seasonal variation." [USACE 2020a: Executive Summary Page 63]

3.c "The duration of impacts to surface water hydrology would vary from temporary to permanent. The geographic extent of the impact on the NFK and the SFK rivers may extend just below the confluence of the two rivers. After the flows combine at the confluence of the NFK and SFK rivers, discernable changes in flow would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River." [USACE 2020a: Page 4.16-2]

EPA Response

These FEIS quotes focus on changes in fish populations, surface water quantities, and streamflow patterns downstream of the mine site. In each case, the FEIS states that effects on these parameters are expected or likely to fall within the range of natural, historic, and seasonal variability. These statements do not mean that the 2020 Mine Plan would not significantly impact aquatic resources at or downstream of the mine site. As discussed in greater detail in Section B.2.2, the habitats that would be lost or degraded as a result of the discharge of dredged or fill material associated with the construction and operation of the 2020 Mine Plan are highly variable in terms of streamflow, fish densities, water

temperature, and other parameters. This variability is evident even across the relatively limited spatial and temporal scales over which baseline environmental data have been collected in the region.[4]

Because these are highly variable systems, changes associated with construction and operation of the 2020 Mine Plan could fall within the range of recorded natural variability but still represent large impacts to these systems, thereby resulting in unacceptable adverse effects (Section B.2.2). It is important to consider how aquatic resources would be affected not just by the magnitude of expected changes, but also by their disruption of natural temporal and spatial patterns of variability at biologically meaningful scales. For example, streamflow variability is critical to the structure and function of these ecosystems. As discussed in Section B.3.2, the discharge of treated water would transform the naturally varying and unregulated surface water flows in the headwaters of the NFK and SFK into less variable streamflows that at times are dramatically increased from natural conditions, due to uniform WTP discharges of regulated process-water to surface waters. The FEIS does not explain how streamflow changes associated with the construction and operation of the 2020 Mine Plan would alter natural flow patterns and variability,[5] nor consider how these changes in the natural flow regime would affect physical habitat, water quality, and the full suite of organisms adapted to these systems (Section B.3.1).

Quote 3.a states that "…impacts to anadromous and resident fish populations from these direct habitat losses would not be measurable, and would be expected to fall within the range of natural variability." As discussed above, this statement tells us very little about the severity of project impacts. The 2020 Mine Plan will permanently reduce the total area of habitat for anadromous and resident fishes. As detailed in Section 4 of the final determination, the productivity of remaining downstream fish habitat also will be permanently degraded due to alterations in streamflow, water chemistry, and water temperature and the loss of ecological subsidies from impacted upstream habitats. This permanent loss of productive capacity will reduce the ability of the habitat to support anadromous and resident fish populations and will reduce the range of variability for fish populations relative to current conditions.

Quote 3.b addresses State-permitted water withdrawals from surface waters and indicates that such withdrawals would primarily occur along the transportation corridor during the 4-year construction period. The FEIS notes only that permit requirements would likely maintain streamflows or waterbody volumes within the limits of historic and seasonal variation. Quote 3.b is not relevant to EPA's final determination because EPA's determinations of unacceptable adverse effects are not based on aquatic

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[4] EPA recognizes that the SFK, NFK, and UTC are relatively well-sampled streams, compared with other streams in the region, due to PLP's efforts to collect environmental baseline data in areas draining the Pebble deposit area; however, these data are still spatially and temporally limited and, thus, should be interpreted with caution (see Sections B.1 and B.2 for more detail).

[5] The FEIS acknowledges that "[f]lood magnitude and frequency on the NFK and SFK rivers could potentially change as a result of mine development" and that "[t]he geographic extent of potential changes to flood magnitude on the NFK and SFK could extend just below the confluence of the two rivers," (USACE 2020: Page 4.16-18), but does not discuss how specific flood events, such as channel-forming flows or bankfull flows that occur every 1.5 to 2 years, would be altered; what such changes would mean for stream stability; or how such changes would affect aquatic habitats and species.

resource impacts resulting from surface water withdrawals, short-term impacts from construction, or impacts along the transportation corridor.

Quote 3.c makes two points: (1) that impacts to surface water hydrology from construction and operation of the 2020 Mine Plan would occur in all reaches of the NFK and SFK downstream of the mine site; and (2) that any changes in streamflow below the confluence of the NFK and SFK "…are expected to be within historic and seasonal variation in the Koktuli River." Regarding the first point, there are approximately 61 miles of mainstem habitat between the mine site and the confluence of the NFK and SFK—that is, there are 38 miles in the NFK and 23 miles in the SFK that support anadromous fishes and would experience impacts to surface water hydrology. Changes in natural flow patterns and variability would be most dramatic at upstream reaches closer to the mine site. For example, average streamflows in April are predicted to increase by more than 100 percent within the SFK Reach D and NFK Reaches C and D due to construction and operation of the 2020 Mine Plan. These predicted changes would constitute a significant alteration of natural flow conditions. Section 4.2.4 of the final determination addresses how EPA considered adverse effects resulting from changes in streamflow in downstream anadromous fish streams. The second point in quote 3.c is not relevant to the final determination because EPA's determination of unacceptable adverse effects is not based on predicted streamflow changes within the Koktuli River downstream of the confluence of the NFK and SFK.

4. Conclusions related to predicted habitat availability

Commenters cited two FEIS quotes related to predicted fish habitat availability that they contend contradict EPA's conclusions in the final determination.

Cited FEIS Quotes

4.a "With few exceptions, predicted changes in habitat in the modeled portion of the upper mainstem Koktuli River (upstream of the Swan River) are near zero or positive, suggesting that project effects from flow changes would not negatively impact reaches downstream of the NFK and SFK confluence, or in UTC." [USACE 2020a: Page 4.24-13]

4.b "In mainstem reaches, few changes in surface water flows are expected to result in decreased suitable habitat exceeding 2 percent. Most changes would be expected to increase suitable habitat (see Table K4.24-1), partially because of the WTP treated water discharge into the mainstem reaches (or tributaries immediately upstream of the mainstems) of the NFK, SFK, and UTC, according to the species and life-stage priorities listed in Table 4.24-2. Figure 4.24-2 shows that 81 to 90 percent of expected changes in suitable spawning habitat would be positive, or within 2 percent of pre-mine conditions, with more predicted increases in habitat than decreases, for both anadromous and resident fish species in an average water year scenario. All predicted decreases in suitable habitat exceeding 10 percent are from tributaries NK 1.190 and SK 1.190." [USACE 2020a: Page 4.24-14]

EPA Response

As detailed in Appendix B, EPA has concerns about how the PHABSIM analysis was conducted and applied in the FEIS. The FEIS assumed that PHABSIM-generated changes in depth and velocity adequately capture effects on fish habitat, despite the fact that many other parameters influence fish habitat use (see Section B.4 for a more detailed discussion of EPA's concerns). EPA considered the PHABSIM analysis included in the FEIS when developing the proposed determination, the recommended determination, and this final determination. However, EPA also recognizes the importance of natural flow regimes in maintaining habitat-forming processes and the biotic integrity of salmon ecosystems in the SFK, NFK, and UTC watersheds (EPA 2014: Chapter 7). Thus, EPA used projected streamflow changes from the natural hydrograph to evaluate effects resulting from the discharge of dredged or fill material associated with the construction and operation of the 2020 Mine Plan. Such an approach considers changes in the natural hydrograph that affect the hydrogeomorphic processes creating, shaping, and maintaining aquatic habitats, rather than focusing on an individual species, a specific guild of species (e.g., Pacific salmon), or a specific life stage (e.g., spawning adults) that may have different spatial and temporal habitat requirements than other biota in the natural system. Alteration of these hydrogeomorphic processes affects habitat-forming processes, as well as habitat conditions beyond water depth and velocity (see Section B.4).

The FEIS conclusion that most changes in fish spawning and rearing habitats predicted to result from construction and operation of the 2020 Mine Plan would be "near zero or positive" is flawed for several reasons (see Section B.4). For example, the FEIS assumes that increases in winter flows would increase fish habitat use, although this assumption is not supported by available data at the mine site. The FEIS does not include any winter fish distribution and abundance data and does not evaluate potential losses of incubating eggs due to increased winter flows. Predicting how flow changes would affect winter habitat is particularly challenging given the lack of streamflow measurements collected during winter months, lack of fish habitat use information during winter months (e.g., calibration data), and the complex interactions of groundwater and surface water that would be disrupted due to streamflow alterations with potential implications for winter ice-free habitat and water temperatures.

Aquatic biota are adapted to the natural flow regimes of their habitats, and streamflow changes occurring due to the construction and operation of the 2020 Mine plan will disrupt all components of the natural flow regime. The FEIS did not evaluate the effects of this disruption on habitat availability and use for all Pacific salmon species at all life stages. Instead, the FEIS assumes, without explanation or justification, that more water translates to more fish habitat, even when this assumption is clearly not supported by the available data. For example, field data demonstrate decreased habitat use by juvenile Coho, Sockeye, and Chinook salmon with increasing depth (Figure B-2): as water depth increased above approximately 2.1 feet, the probability that juvenile Coho and Chinook salmon would be found decreased, with no juveniles of either species found at water depths above roughly 3.7 feet. The FEIS also did not provide data on fish distribution and abundance data in overwintering areas or consider potential impacts on salmon egg incubation.

The FEIS did not provide any specific details about how treated water discharges would be managed and monitored to optimize conditions for "species and life-stage priorities" (quote 4.b), and EPA questions whether the goal of habitat optimization is attainable. Specifically, EPA questions, among other things, whether habitat optimization is possible given the limitations of the flow-habitat model development and the limitations of the planned streamflow monitoring program (see Sections B.3.2 and B.4.3 for further discussion).

Quote 4.a states that streamflow changes associated with construction and operation of the 2020 Mine Plan "would not negatively impact reaches downstream of the NFK and SFK confluence." As explained above, EPA's final determination is not based on impacts below the confluence of the NFK and SFK. EPA's final determination is based solely on the unacceptable adverse effects on fishery areas within the NFK, SFK, and UTC watersheds.

5. Conclusions related to cumulative effects

Commenters cited one FEIS quote related to cumulative effects of the Expanded Mine Scenario, which they believe contradict EPA's conclusions in the final determination.

Cited FEIS Quote

5.a. "Overall, the contribution of Alternative 1a to cumulative effects to aquatic resources, when taking other past, present, and RFFAs [Reasonably Foreseeable Future Actions] into account, would be minor to moderate in terms of magnitude, duration, and extent, given the documented habitat use by fish, existing habitat potential, and permit requirements regarding fish and aquatic habitat protection at stream crossings." [USACE 2020a: Page 4.24-70]

EPA Response

The cumulative effects of the Expanded Mine Scenario are not a basis for this final determination (see Section 4 of the final determination), and as such quote 5.a is not relevant to this final determination. Nevertheless, EPA provides the following in response to comments. The conclusion that cumulative effects to aquatic resources that would result under the Expanded Mine Scenario would be "minor to moderate" is based on "documented habitat use by fish" and estimates of "existing habitat potential." As detailed in Section B.1.1, FEIS conclusions that the loss of stream habitats would be inconsequential for fish populations appear to be based on an assumption that the relative quality of these habitats is low and that these habitats have minimal influence on downstream waters. These assumptions and, thus, the conclusions based on them, are not supported by the available information about these habitats or the current science surrounding the importance of headwater systems (see Sections B.1 and B.2 for additional discussion related to this point). Section 3 and Appendix B of the final determination discuss the importance of the aquatic resources that would be impacted by the discharge of dredged or fill material associated with the construction and operation of the 2020 Mine Plan and the Expanded Mine Scenario in detail. The factual record strongly supports EPA's conclusion that the habitats that would be lost or damaged at the mine site (1) are productive habitats for aquatic biota, including fishes, and (2) support the productivity of downstream anadromous waters.

In fact, the FEIS documents the large amounts of habitat loss that would occur under the Expanded Mine Scenario:

- "The cumulative effects of indirect impacts described above [changes in surface and groundwater flows, increased sediment, changes in water temperature] are expected to change overall productivity in the NFK and SFK drainages…" [USACE 2020a: Page 4.24-28]
- "At the mine site, an additional 35 miles of anadromous stream habitat would be lost in the SFK and UTC drainages, including the entire footprint of Frying Pan Lake, which would [sic] inundated by the south collection pond, potentially affecting sockeye, coho, chum, and Chinook salmon." [USACE 2020a: Page 4.24-64.]
- "The Pebble Project expansion scenario footprint would impact approximately 31,892 acres, compared to 9,612 acres…" [USACE 2020a: Page 4.24-65]
- "Expansion of the project would contribute to cumulative effects on wetlands and other waters through the excavation and placement of fill, fragmentation of habitat, deposition of dust, and dewatering. These actions would be expected to contribute to the permanent loss of habitat and associated reduction in habitat connectivity, ecological function, and the perceived values of wetlands and other waters." [USACE 2020a: Page 4.22-115]
- "With expansion, the duration of these impacts would be extended by an additional 58 years of mining and 20 years of additional milling, extending the intermittent impacts and increasing the likelihood of impacts from spills." [USACE 2020a: Page 4.24-65]

The discharge of dredged or fill material associated with the construction and operation of the 2020 Mine Plan will result in the permanent loss of approximately 8.5 miles of streams in the NFK watershed with documented occurrence of anadromous fishes, specifically Coho and Chinook salmon. The Expanded Mine Scenario would eliminate an additional 35 miles of streams in the SFK and UTC watersheds with documented occurrence of anadromous fishes (USACE 2020a: Section 4.24). The additional stream losses that would occur as a result of the Expanded Mine Scenario represent 25.7 percent of anadromous fish streams across the SFK and UTC watersheds combined.[6] The discharge of dredged or fill material associated with the Expanded Mine Scenario also would result in the permanent loss of an additional 295.5 miles of streams that support downstream anadromous fish streams across the SFK and UTC watersheds, most of which would be perennial streams (USACE 2020a: Table 4.22-40).

The discharge of dredged or fill material associated with the Expanded Mine Scenario would result in the permanent loss of an additional 8,756 acres of wetlands and other waters in the SFK and UTC watersheds (USACE 2020a: Table 4.22-40) and the complete loss of 544 acres of lakes and ponds with documented anadromous fish use (Giefer and Graziano 2022), including the 150-acre Frying Pan Lake in the SFK watershed. Frying Pan Lake, which would be inundated by the south collection pond, provides

[6] The SFK watershed contains 60.0 miles of anadromous waters and the UTC watershed contains 76.2 miles of anadromous waters, based on AWC and PLP stream layers (USACE 2020a: Section 3.24).

rearing habitat for Sockeye Salmon, Arctic Grayling, Northern Pike, whitefish, stickleback, and sculpin. Across the SFK, NFK, and UTC watersheds, the discharge of dredged or fill material associated with the Expanded Mine Scenario would result in losses of documented Sockeye, Coho, Chinook, and Chum salmon habitat (USACE 2020a: Section 4.24). The functional and productive capacity of these lost fishery areas—for anadromous fishes, as well as for resident fishes and other aquatic biota—would be zero, and the functional and productive capacity of remaining downstream fishery areas would be significantly damaged.

As Table 4-6 of the final determination illustrates, the discharge of dredged or fill material associated with the Expanded Mine Scenario would cumulatively result in the following losses of anadromous stream habitat in the SFK, NFK, and UTC watersheds: 32.8 miles documented to support Coho Salmon; 13.7 miles documented to support Chinook Salmon; 7.8 miles documented to support Sockeye Salmon; and 1.6 miles documented to support Chum Salmon. Sections B.1 and B.2 explain why these values likely represent minimum estimates of actual impacts, and even these minimum estimates represent extraordinary levels of anadromous habitat loss.

EPA assumes that construction and operation of the 2020 Mine Plan and the Expanded Mine Scenario would involve implementation of all required stream crossing (and other) protections. Further, any accidents or failures of these required safeguards, although likely (see Section 6 of the final determination), are not a basis for this final determination.

6. Conclusions related to the coexistence of mining and fisheries in other watersheds

Commenters cited one FEIS quote that suggests that construction and operation of the 2020 Mine Plan would not be expected to affect salmon populations at the mine site because salmon fisheries and resource extraction activities have co-existed elsewhere in Alaska.

Cited FEIS Quote

6.a “Other salmon fisheries in Alaska exist in conjunction with non-renewable resource extraction industries. For example, the Cook Inlet salmon fisheries exist in an active oil and gas basin and have developed headwaters of Anchorage and the Matanuska-Susitna areas. The Copper River salmon fishery occurs in a watershed with the remains of the historic Kennecott Copper Mine and the Trans Alaska Pipeline System in the headwaters of portions of the fishery. Both fisheries average higher prices per pound than the Bristol Bay Salmon Fishery.” [USACE 2020a: Executive Summary Page 86]

EPA Response

This quote does not address the expected impacts of the discharge of dredged or fill material associated with the construction and operation of the 2020 Mine Plan or the development of the Pebble deposit, which is the sole focus of this final determination. As explained in detail in Section 4, EPA has determined that the discharge of dredged or fill material associated with the construction and operation

of the 2020 Mine Plan will result in unacceptable adverse effects on fishery areas in the NFK, SFK, and UTC. The FEIS acknowledges that the examples cited in this quote are not relevant to assessment of impacts associated with construction and operation of the 2020 Mine Plan, stating that "…no other wild salmon fishery in the world exists in conjunction with an active mine of this size, so existing examples are limited in their usefulness as working comparisons" (USACE 2020a: Page 4.6-9). Evaluating the impacts that will result from the discharge of dredged or fill material associated with construction and operation of the 2020 Mine Plan or similar development of the Pebble deposit requires a place-based analysis that accounts for the nature and magnitude of the potential adverse effects and the ecological significance of the region's salmon populations.

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APPENDIX C

TECHNICAL EVALUATION OF POTENTIAL COMPENSATORY MITIGATION MEASURES

CONTENTS

Acronyms and Abbreviations

BBA	Bristol Bay Assessment
CWA	Clean Water Act
DA	Department of the Army
EBD	Environmental Baseline Document
EPA	Environmental Protection Agency
FEIS	Final Environmental Impact Statement
MOA	Memorandum of Agreement
NFK	North Fork Koktuli River
NOAA	National Oceanic and Atmospheric Administration
PLP	Pebble Limited Partnership
ROD	Record of Decision
SFK	South Fork Koktuli River
TDS	total dissolved solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geologic Survey
UTC	Upper Talarik Creek
WTP	wastewater treatment plant

EXECUTIVE SUMMARY

Compensatory mitigation refers to the restoration, establishment, enhancement, and/or in certain circumstances preservation of wetlands, streams, or other aquatic resources. Compensatory mitigation regulations jointly promulgated by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) state that "the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by [Clean Water Act (CWA) Section 404 permits issued by USACE]" (40 CFR 230.93(a)(1)). Compensatory mitigation enters the analysis only after a proposed project design has incorporated all appropriate and practicable means to avoid and minimize adverse impacts on aquatic resources (40 Code of Federal Regulations [CFR] 230.91(c)).

The Pebble Limited Partnership (PLP) has proposed to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine in the Bristol Bay watershed in southwest Alaska (i.e., the 2020 Mine Plan) (PLP 2020b). In its 2023 *Final Determination of the U.S. Environmental Protection Agency Pursuant to Section 404(c) of the Clean Water Act: Pebble Deposit Area, Southwest Alaska*, EPA finds that the estimated loss and degradation of wetlands, streams, and other aquatic resources from the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan will have unacceptable adverse effects on anadromous fishery areas.

During development and finalization of the Bristol Bay Assessment (BBA) (EPA 2014) between 2011 and 2014 and review of an earlier 404(c) proposed determination regarding the Pebble deposit published in 2014, PLP and other commenters suggested an array of measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fish from the discharge of dredged or fill material associated with developing the Pebble deposit.

This appendix provides a detailed technical evaluation of each of these measures, for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this final determination to an acceptable level.

SECTION 1. COMPENSATORY MITIGATION BACKGROUND

Compensatory mitigation is defined as the restoration, establishment, enhancement, and/or, in certain circumstances, preservation of wetlands, streams, or other aquatic resources conducted specifically for the purpose of offsetting unavoidable authorized impacts to these types of resources (40 Code of Federal Regulations [CFR] 230.92, Hough and Robertson 2009). According to compensatory mitigation regulations jointly promulgated by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE), "the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by [Clean Water Act (CWA) Section 404 permits issued by USACE]" (40 CFR 230.93(a)(1)).

CWA Section 404 permitting requirements for compensatory mitigation are based on what is "practicable and capable of compensating for the aquatic resource functions that will be lost as a result of the permitted activity" (40 CFR 230.93(a)(1)). In determining what type of compensatory mitigation will be "environmentally preferable," USACE "must assess the likelihood for ecological success and sustainability, the location of the compensation site relative to the impact site and their significance within the watershed, and the costs of the compensatory mitigation project" (40 CFR 230.93(a)(1)). Furthermore, compensatory mitigation requirements must be commensurate with the amount and type of impact associated with a particular CWA Section 404 permit (40 CFR 230.93(a)(1)).

1.1 Location, Type, and Amount of Compensation

Regulations regarding compensatory mitigation require the use of a watershed approach to "establish compensatory mitigation requirements in [Department of the Army] permits to the extent appropriate and practicable" (40 CFR 230.93(c)(1)). Under these regulations, the watershed approach to compensatory mitigation site selection and planning is an analytical process for making compensatory mitigation decisions that support the sustainability or improvement of aquatic resources in a watershed. It involves consideration of watershed needs and how locations and types of compensatory mitigation projects address those needs (40 CFR 230.92). The regulations specifically state that compensatory mitigation generally should occur within the same watershed as the impact site and in a location where it is most likely to successfully replace lost functions and services (40 CFR 230.93(b)(1)). The goal of this watershed approach is to "maintain and improve the quality and quantity of aquatic resources within watersheds through strategic selection of compensatory mitigation sites" (40 CFR 230.93(c)(1)).

The regulations emphasize using existing watershed plans to inform compensatory mitigation decisions when such plans are determined to be appropriate for use in this context (40 CFR 230.93(c)(1)). Where appropriate plans do not exist, the regulations describe the types of considerations and information that should be used to support a watershed approach to compensation decision-making. Central to the

watershed approach is consideration of how the types and locations of potential compensatory mitigation projects would sustain aquatic resource functions in the watershed. To achieve that goal, the regulations emphasize that mitigation projects should, where practicable, replace the suite of functions typically provided by the affected aquatic resource, rather than focus on specific individual functions (40 CFR 230.93(c)(2)). For this purpose, "watershed" means an "area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean" (40 CFR 230.92). Although there is flexibility in defining geographic scale, the watershed "should not be larger than is appropriate to ensure that the aquatic resources provided through compensation activities will effectively compensate for adverse environmental impacts resulting from [permitted] activities" (40 CFR 230.93(c)(4)).

With regard to type, in-kind mitigation (i.e., involving resources similar to those being impacted) is generally preferable to out-of-kind mitigation, because it is most likely to compensate for functions lost at the impact site (40 CFR 230.93(e)(1)). Furthermore, the regulations recognize that, for difficult-to-replace resources such as bogs, fens, springs, and streams, in-kind "rehabilitation, enhancement, or preservation" should be the compensation of choice, given the greater likelihood of success of those types of mitigation (40 CFR 230.93(e)(3)).

The amount of compensatory mitigation required must be, to the extent practicable, "sufficient to replace lost aquatic resource functions" (40 CFR 230.93(f)(1)), as determined through the use of a functional or condition assessment. If an applicable assessment methodology is not available, the regulations require a minimum one-to-one acreage or linear foot compensation ratio (40 CFR 230.93(f)(1)). Certain circumstances require higher ratios, even in the absence of an assessment methodology (e.g., use of preservation, lower likelihood of success, differences in functionality between the impact site and compensation project, difficulty of restoring lost functions, and the distance between the impact and compensation sites) (40 CFR 230.93(f)(2)).

1.2 Compensatory Mitigation Guidance for Alaska

In addition to the federal regulations regarding compensatory mitigation, EPA and the DA have also developed compensatory mitigation guidance applicable specifically to Alaska in a 2018 Memorandum of Agreement (MOA) (EPA and DA 2018).[1] The 2018 MOA provides guidance regarding flexibilities that exist in the mitigation requirements for CWA Section 404 permits, and how those flexibilities can be applied in Alaska given the abundance of wetlands and unique circumstances involved with CWA Section 404 permitting in the state. Accordingly, the 2018 MOA recognizes that restoring, enhancing, or establishing wetlands for compensatory mitigation may not be practicable due to limited availability of sites and/or technical or logistical limitations. It also recognizes that compensatory mitigation options

[1] This MOA updates and replaces the EPA and DA Memoranda entitled *Clarification of the Clean Water Act Section 404 Memorandum of Agreement on Mitigation*, dated January 24, 1992, and *Statements on the Mitigation Sequence and No Net Loss of Wetlands in Alaska*, dated May 13, 1994.

over a larger watershed scale may be appropriate given that compensation options are frequently limited at a smaller watershed scale.

The 2018 MOA also identifies when compensatory mitigation may be required to ensure that an activity requiring a CWA Section 404 permit complies with the CWA Section 404(b)(1) Guidelines (40 CFR Part 230.91(c)(2)). The 2018 MOA provides the following examples.

- Compensatory mitigation may be required to ensure that discharges do not cause or contribute to a violation of water quality standards or jeopardize a threatened or endangered species or result in the destruction or adverse modification of critical habitat under the Endangered Species Act (40 CFR Part 230.10(b)).
- Compensatory mitigation may be required to ensure that discharges do not cause or contribute to significant degradation (40 CFR Part 230.10(c)).
- The CWA Section 404(b)(1) Guidelines also require compensatory mitigation measures when appropriate and practicable (40 CFR Parts 230.10(d), 230.12, 230.91, and 230.93(a)(1)).

The 2018 MOA also notes that during the CWA Section 404(b)(1) Guidelines compliance analysis, USACE may determine that a CWA Section 404 permit for a proposed discharge cannot be issued because of a lack of appropriate and practicable compensatory mitigation options (40 CFR Part 230.91(c)(3)).

It is important to remember that decisions regarding the appropriate type, amount, and location of compensatory mitigation are made on a case-by-case basis and depend on a number of factors, including the type, amount, and location of aquatic resources being impacted.

SECTION 2. IMPORTANT ECOLOGICAL FUNCTIONS AND SERVICES PROVIDED BY AFFECTED STREAMS AND WETLANDS

2.1 Aquatic Resources Affected at the Proposed Mine Site

As discussed in Section 2 of the final determination, the Pebble Limited Partnership (PLP) has proposed to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine in the Bristol Bay watershed in southwest Alaska. The project (i.e., the 2020 Mine Plan) consists of four primary components: the mine site, the port, the transportation corridor including concentrate and water return pipelines, and the natural gas pipeline and fiber optic cable (PLP 2020b).[2]

As discussed in Section 4 of the final determination, USACE's Final Environmental Impact Statement (FEIS) and Record of Decision (ROD) for the project estimate that the discharge of dredged or fill material at the mine site would result in the total loss of approximately 99.7 miles of stream habitat, representing approximately 8.5 miles of anadromous fish streams and approximately 91 miles of additional streams that support anadromous fish streams. Such discharges of dredged or fill material also would result in the total loss of approximately 2,108 acres of wetlands and other waters in the South Fork Koktuli River (SFK) and North Fork Koktuli River (NFK) watersheds that support anadromous fish streams (USACE 2020a and 2020b).[3] Section 4 of the final determination also discusses how discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would adversely affect approximately 29 miles of anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow. In the final determination, EPA finds that certain discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan will have unacceptable adverse effects on anadromous fishery areas.

2.2 Importance of Affected Aquatic Resources

Section 3 of the final determination provides a detailed description of the importance of the region's ecological resources. As discussed in Section 3 of the final determination, because of its climate, geology, hydrology, pristine environment, and other characteristics, the Bristol Bay watershed is home to

[2] The final determination focuses on the adverse effects of discharges of dredged or fill material associated with the mine site(see final determination: Section 2.1.2).

[3] Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this final determination, "anadromous fishes" refers only to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*). Impact values cited here come from the ROD, which provides updates to the impact values provided in the FEIS.

abundant, diverse, and productive aquatic habitats (final determination: Figure ES-1). These streams, rivers, wetlands, lakes, and ponds support world-class commercial, subsistence, and recreational fisheries for multiple species of Pacific salmon, as well as numerous other fish species valued as subsistence and recreational resources (final determination: Section 3.3).

The productivity and diversity of the watershed's aquatic habitats are closely tied to the productivity and diversity of its fisheries. The waters of the SFK, NFK, and Upper Talarik Creek (UTC) watersheds are important for maintaining the integrity, productivity, and sustainability of the region's salmon and non-salmon fishery resources (final determination: Sections 3.2 and 3.3). The Pebble deposit overlies portions of the SFK, NFK, and UTC watersheds, and these areas would be most directly affected by mine development at the Pebble deposit.

Streams and lakes in the SFK, NFK, and UTC watersheds are ideal for maintaining high levels of fish production, with clean, cold water, gravel substrates, and abundant areas of groundwater upwelling. These conditions create preferred salmon spawning habitat and provide favorable conditions for egg incubation and survival. Figure 4-3 of the final determination illustrates reported distributions for all five species of Pacific salmon (Coho [*Oncorhynchus kisutch*], Chinook [*O. tshawytscha*], Sockeye [*O. nerka*], Chum [*O. keta*], and Pink [*O. gorbuscha*]) in these three watersheds. Streams and lakes in the SFK, NFK, and UTC watersheds also provide high-quality habitat for fishes, such as Rainbow Trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), Arctic Grayling (*Thymallus arcticus*), and Northern Pike (*Esox lucius*). Wetlands provide essential off-channel habitats that protect young Coho Salmon and other species, as well as provide spawning areas for Northern Pike. All of these species move throughout the region's freshwater habitats during their life cycles, and all are fished—commercially, for subsistence use, and recreationally—in downstream waters. Thus, the intact headwater-to-larger river systems found in the SFK, NFK, and UTC watersheds, with their associated wetlands, help sustain the overall productivity of these fishery areas (final determination: Sections 3.2 and 3.3).

Not only do the streams, wetlands, and ponds of the SFK, NFK, and UTC watersheds directly provide habitat for salmon and other fishes, they also provide critical support for downstream habitats. By contributing water, organic matter, and macroinvertebrates to downstream systems, these headwater areas help maintain downstream habitats and fuel their fish productivity. Together, these functions—direct provision of high-quality habitat and indirect provision of other resources to downstream habitats—help support the valuable fisheries of the Bristol Bay watershed (final determination: Section 3.2).

This support is vital for populations of Coho, Chinook, and Sockeye salmon in these watersheds. Chinook Salmon are the rarest of the North American Pacific salmon species but are a critical subsistence resource, particularly along the Nushagak River. The SFK, NFK, and UTC watersheds support discrete populations of Sockeye Salmon that are genetically programmed to return to specific localized reaches or habitats to spawn; they likely do the same for Coho and Chinook salmon (final determination: Section 3.3.3). This portfolio of multiple small populations is essential for maintaining the genetic diversity and,

thus, the stability and productivity of the region's overall salmon stocks (i.e., the portfolio effect) (final determination: Section 3.3.3).

2.3 Identifying the Appropriate Watershed Scale for Compensatory Mitigation

As previously noted, the regulations regarding compensatory mitigation specifically state that compensatory mitigation generally should occur within the same watershed as the impact site and in a location where it is most likely to successfully replace lost functions and services (40 CFR 230.93(b)(1)).

For the impacts of the mine site associated with the 2020 Mine Plan, ecological functions and services would be most directly affected in the SFK, NFK, and UTC watersheds. Accordingly, the most appropriate geographic scale at which to compensate for any unavoidable impacts resulting from such a project would be within these same watersheds, as these locations would offer the greatest likelihood that compensation measures would replace the "suite of functions typically provided by the affected aquatic resource" (40 CFR 230.93(c)(2), Yocom and Bernard 2013). An important consideration is that salmon populations in these watersheds possess unique adaptations to local environmental conditions, as suggested by recent research in the region (Olsen et al. 2003, Ramstad et al. 2010, Quinn et al. 2012, Dann et al. 2012, Shedd et al. 2016, Brennan et al. 2019). Accordingly, maintenance of local biocomplexity (i.e., salmon genetic, behavioral, and phenotypic variation) and the environmental template upon which biocomplexity develops will be important for sustaining resilience of these populations (Hilborn et al. 2003, Schindler et al. 2010, Griffiths et al. 2014, Brennan et al. 2019). Thus, the most appropriate spatial scale and context for compensation would be within the local watersheds where impacts on salmon populations occur.

If there are no practicable or appropriate opportunities to provide compensation in these watersheds, exploring options in adjoining watersheds may be appropriate. However, defining the watershed scale too broadly would likely fail to ensure that wetland, stream, and associated fish losses in the SFK, NFK, and UTC watersheds would be addressed, because compensation in a different watershed(s) would not reduce the severity of the impacts to aquatic resources in the affected watersheds. Similarly, compensation in different watersheds would not address impacts to the subsistence fishery where users depend on a specific temporal and spatial distribution of fish to ensure nutritional needs and cultural values are maintained (EPA 2014: Chapter 12).

SECTION 3. REVIEW OF ADDITIONAL POTENTIAL COMPENSATORY MITIGATION MEASURES

During development and finalization of the Bristol Bay Assessment (BBA) between 2011 and 2014 and during public review of an earlier 404(c) proposed determination regarding the Pebble deposit published in 2014, PLP and other commenters suggested an array of measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fish from the discharge of dredged or fill material associated with developing the Pebble deposit. This section provides a technical evaluation of the likely efficacy, applicability, and sustainability of these additional measures in reducing the unavoidable aquatic resource impacts estimated for the 2020 Mine Plan to an acceptable level. Since mitigation bank and in-lieu fee program options are not available, all of these additional measures would involve permittee-responsible compensatory mitigation.[4]

Neither PLP, the State of Alaska, USACE, nor any other party suggested any additional compensation measures during (1) the initial stakeholder consultation with EPA prior to issuance of the 2022 Proposed Determination, (2) the public comment period on the 2022 Proposed Determination, or (3) final consultation on the recommended determination in December 2022.

3.1 Permittee-Responsible Compensatory Mitigation

3.1.1 Compensation Measures Suggested within the SFK, NFK, and UTC Watersheds

This section discusses specific suggestions for potential compensation measures within the SFK, NFK, and UTC watersheds that were provided in the public and peer review comments on the BBA and 2014 Proposed Determination.

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[4] Mitigation banks and in-lieu fee programs are other mechanisms for satisfying compensatory mitigation requirements that rely on third-party providers (40 CFR 230.92). Should a mitigation bank or in-lieu fee sponsor pursue the establishment of mitigation bank or in-lieu fee program sites to address impacts of the nature and magnitude estimated for the 2020 Mine Plan, they would encounter the same challenges described in Section 3 of this appendix. Permittee-responsible mitigation means an aquatic resource restoration, establishment, enhancement, and/or preservation activity undertaken by the permittee to provide compensatory mitigation for which the permittee retains full responsibility (40 CFR 230.92).

3.1.1.1 Increase Habitat Connectivity

Several commenters recommended actions to increase connectivity between aquatic habitats, which are discussed in this section. Connectivity among aquatic habitats within stream networks is an important attribute influencing the ability of mobile aquatic taxa to utilize the diversity and extent of habitats within those networks. Within riverine floodplain systems, a complex array of habitats can develop that express varying degrees of surface and sub-surface water connectivity to main channels (Stanford and Ward 1993). In the study area, off-channel floodplain habitats can include side channels (both inlet and outlet connections to main channel), various types of single-connection habitats including alcoves and percolation channels, and pools and ponds with no surface connection to the main channel during certain flow conditions (PLP 2011: Appendix 15.1D). Beavers (*Castor canadensis*) can be very important modifiers and creators of habitat in these off-channel systems (Pollock et al. 2003, Rosell et al. 2005). As a result of their morphology and variable hydrology, the degree of surface-water connectivity and the ability of fish to move among floodplain habitats changes with surface water levels. Connectivity for fish movement at larger spatial scales within watersheds is influenced by barriers to longitudinal movements and migrations. Examples include dams and waterfalls.

Efforts to manage or enhance connectivity within aquatic systems have primarily focused on watersheds altered by human activities, where land uses and water utilization have led to aquatic habitat fragmentation. Specific activities to increase habitat connectivity within human-dominated stream-wetland systems may include the following.

- Improving access around real or perceived barriers to migration (including dams constructed by humans or beavers).
- Removing or retrofitting of road culverts.
- Excavating and engineering of channels to connect isolated wetlands and ponds to main channels.
- Reconnection of historic floodplains via levee removal or other channel engineering.

Within watersheds minimally affected by human activity, efforts to increase connectivity may include creation of passage around barrier waterfalls to expand the availability of habitat for species like Pacific salmon. Removal of human-created dams do not offer any opportunities for habitat improvement or expansion in the Nushagak or Kvichak River watersheds because they are absent, so they are not discussed further. As stated earlier, this is primarily a roadless area, so road stream crossing retrofits presently offer few if any opportunities for habitat improvement or expansion within the SFK, NFK, and UTC watersheds, but exist elsewhere in the larger Nushagak and Kvichak River watersheds and are discussed in Section 3.1.2. Here, beaver dam removal and engineered connections to variably connected floodplain habitats, and habitats upstream of barrier waterfalls are discussed. For each of these measures, the potential applicability, suitability, and effectiveness as mitigation tools within the SFK, NFK, and UTC watersheds are addressed.

3.1.1.1.1 Remove Beaver Dams

Two commenters suggested the removal of beaver dams as part of a potential compensation strategy that included beaver management. Presumably, the rationale for this recommendation is that beaver dams can block fish passage, limiting fish access to otherwise suitable habitat, thus, the removal of beaver dams could increase the amount of available fish habitat. This rationale is based on early research that led to the common fish management practice of removing beaver dams to protect certain fish populations like trout (Salyer 1934, Reid 1952, *in* Pollock et al. 2004). However, more recent research has documented numerous benefits of beaver ponds to fish populations and habitat (Murphy et al. 1989, Pollock et al. 2003). For example, Bustard and Narver (1975) found that a series of beaver ponds on Vancouver Island had a survival rate for overwintering juvenile Coho Salmon that was twice as high as the 35 percent estimated for the entire stream. Pollock et al. (2004) estimated a 61 percent reduction in summer habitat capacity relative to historical levels, largely due to the loss of beaver ponds, for Coho Salmon in one Washington watershed.

A recent review by Larsen et al. (2021) describes the extensive and complex ways in which beavers modify stream ecosystems. Increases in habitat complexity and availability of ponded and productive floodplain habitats associated with beaver activity can result in positive impacts on Sockeye, Coho, and Chinook salmon, as well as Dolly Varden, Rainbow Trout, and Steelhead (Kemp et al. 2012). Using meta-analysis and weight-of-evidence methodology, Kemp et al. (2012) showed that most (71.4 percent) negative effects cited, such as low dissolved oxygen and impediment to fish movement, lack supportive data and are speculative in nature, whereas the majority (51.1 percent) of positive impacts cited are quantitative in nature and well supported by data. In addition to increased invertebrate (i.e., food) production and habitat heterogeneity, the study cited the importance of beaver ponds as rearing habitat due to the increased cover and protection that higher levels of woody material and overall structural diversity provide. Other studies from the Pacific Northwest (Nickelson et al. 1992, Collen and Gibson 2001) and Alaska (Lang et al. 2006) have identified beaver ponds as excellent salmon rearing habitat because they have high macrophyte cover, low flow velocity, and increased temperatures, and they trap organic materials and nutrients. DeVries et al. (2012) describe a stream restoration approach that attempts to mimic and facilitate beaver dam creation and the numerous positive benefits for stream habitat and riparian enhancement. Studies in Oregon have shown that salmon abundance is positively related to pool size, especially during low flow conditions (Reeves et al. 2011), and beaver ponds provide particularly large pools. During winter, beaver ponds typically retain liquid water below the frozen surface, providing refugia for species that overwinter in streams and off-channel habitats (Nickelson et al. 1992, Cunjak 1996).

Beaver dams generally do not constitute significant barriers to salmonid migration, even though their semi-permeability may temporarily limit fish movement during periods of low stream flow (Rupp 1955, Gard 1961, Pollock et al. 2003). Even when beaver dams impede fish movements, the effects are typically temporary with higher flows from storm events ultimately overtopping them or blowing them out (Leidholt-Bruner et al. 1992, Kemp et al. 2012). Even the temporary effect may be limited, when seasonal rainfall is at least average (Snodgrass and Meffe 1998, Kemp et al. 2012). Adding to the body of

evidence, Pacific salmon and other migratory fish species commonly occur above beaver dams, including above beaver dams in the study area (PLP 2011: Appendix 15.1D). Other surveys have documented both adult and juvenile Sockeye Salmon, Steelhead, Cutthroat Trout, and char upstream of beaver dams (Swales et al. 1988, Murphy et al. 1989, Pollock et al. 2003).

Beavers preferentially colonize headwater streams and off-channel habitats (Collen and Gibson 2001, Pollock et al. 2003). An October 2005 aerial survey of active beaver dams in the mine site area mapped 113 active beaver colonies (PLP 2011). PLP's Environmental Baseline Document (EBD) highlights the significant role that beaver ponds are currently providing for Pacific salmon in this area:

> [W]hile beaver ponds were relatively scarce in the mainstem UT [UTC], the off-channel habitat study revealed a preponderance of beaver ponds in the off-channel habitats. As in the SFK watershed, beaver ponds accounted for more than 90 percent of the off-channel habitat surveyed. Beaver ponds in the UT provided habitat for adult spawning and juvenile overwintering for Pacific salmon. The water temperature in beaver ponds in the UT was slightly warmer than in other habitat types and thus, beaver ponds may represent a more productive habitat as compared to other mainstem channel habitat types. (PLP 2011)

The current body of literature describing the effects of beaver dams on salmonid species reports more positive associations between beaver dam activity and salmonids than negative associations (Kemp et al. 2012). Hence, removal of beaver dams as a means of compensatory mitigation could lead to a net negative impact on salmonid abundance, growth, and productivity. Moreover, because the mine footprint would eliminate or block several streams with active beaver colonies in the headwaters of the NFK, the benefits provided by those habitats would be part of the suite of functions that compensatory mitigation should aim to offset.

3.1.1.1.2 Connect Off-channel Habitats and Habitat Above Impassable Waterfalls

Off-channel habitats can provide important low-velocity rearing habitats for juvenile salmon and other native fishes. Floodplain-complex habitats including beaver ponds, side channels, oxbow channels, and alcoves can contribute significantly to juvenile salmonid rearing capacity (e.g., Beechie et al. 1994, Ogston et al. 2015). Such habitats are a common feature of unmodified alluvial river corridors. These habitats may express varying degrees of surface-water connectivity to main channels that depend on streamflow stage and natural channel dynamics in unmodified rivers. Off-channel habitats may become isolated from the main channel during certain streamflow conditions due to channel migration or avulsion, and in highly dynamic channels, connectivity may change frequently during bed-mobilizing events (Stanford and Ward 1993). This shifting mosaic of depositional and erosional habitats within the floodplain creates a diverse hydraulic and geomorphic setting, contributing to biocomplexity (Amoros and Bornette 2002). In river systems modified by human activity, isolation or elimination of off-channel habitats has had severe impacts on salmon productivity (e.g., Beechie et al. 1994), and re-connection and re-creation of off-channel habitats are now common tools for increasing juvenile salmonid habitat capacity in those systems (Morley et al. 2005, Roni et al. 2006, Ogston et al. 2015).

Waterfalls or high-gradient stream reaches can prevent fish from accessing upstream habitats, due to velocity barriers or drops that exceed passage capabilities of fish (Reiser et al. 2006). Waters upstream

of barriers may be devoid of all fish life or may contain resident fish species including genetically distinct populations (e.g., Whiteley et al. 2010). Engineered passageways for fish around waterfalls have been used to create access to upstream lakes or stream systems for fish, such as salmon. However, the response of resident fish species to barrier removal and the colonization success of species from downstream habitats may be context dependent and difficult to predict (Kiffney et al. 2009, Pess et al. 2014). Salmon population responses to a fishway in southeast Alaska depended on the species, and the ecological effects of fish passage on the upstream lake system and watershed are not fully understood (Bryant et al. 1999). Burger et al. (2000) provide a well-documented history of colonization of Sockeye Salmon in Frazer Lake, Alaska, above a historically impassable waterfall following passage installation and planting of salmon eggs, fry, and adults above the barrier. Their study documents how differing donor populations, each with different life-history characteristics, contributed differently toward the establishment of populations in the newly accessible habitats (Burger et al. 2000). This study highlights the importance of genetics and life history adaptations of source populations to colonization success.

Creating connectivity between parts of the river network that are naturally disconnected can have adverse ecological effects, including impacts on resident vertebrate and invertebrate communities, as well as disruptions to ecosystem processes. Introduction of fish to fishless areas can lead to altered predator–prey interactions, food web changes, changes in algal production, nutrient cycling, and meta-population dynamics of other vertebrate species (Section 3.1.2.5). For example, previous studies on the introduction of trout species to montane, wilderness lakes have shown that introducing fish to fishless lakes can have substantial impacts on nutrient cycles (Knapp et al. 2001). The risk of disruption to the functions of naturally fishless aquatic ecosystems should be fully evaluated before these approaches are used for the sole purpose of creating new fish habitat area.

The importance of spatial habitat configuration to stream salmonid ecology has been recognized by a wide variety of systems (reviewed by Flitcroft et al. 2019). For example, Rosenfeld and co-authors (Rosenfeld et al. 2008, Rosenfeld and Raeburn 2009) conducted a variety of experiments and monitoring activities within a re-connected river meander in coastal British Columbia to explore the relationship of salmon productivity to habitat features. Their work highlights the importance of habitat configuration. In their study, spacing of pools (foraging habitats for fish) and riffles (source areas for invertebrate prey) was an important factor influencing growth rates of juvenile Coho Salmon. Given the high diversity of channel conditions within floodplain habitats in the SFK, NFK, and UTC watersheds (PLP 2011), it is likely that fish responses to increased connectivity would be highly variable.

Rosenfeld et al. (2008) point out the importance of considering the full suite of factors that influence habitat capacity and productivity when designing restoration or enhancement projects. For instance, attempting to optimize habitat structure for one species may adversely affect species with differing habitat preferences, as demonstrated by Morley et al. (2005) who found differential responses of juvenile Steelhead and juvenile Coho Salmon to conditions in constructed and natural off-channel habitats. Predator–prey relationships also need to be considered. Increased connectivity of off-channel habitats has been proposed as a strategy for enhancing Northern Pike production in northern Canada

(Cott 2004). How increased connectivity in the project area would influence trophic relationships among Northern Pike and salmonids is unknown, although introduced Northern Pike in other areas of Alaska have the potential to reduce local abundances of salmonids via predation (Sepulveda et al. 2013). Bryant et al. (1999) in their study of the effects of improved passage at a waterfall concluded that the effects on food webs, trophic relationships, and genetics among resident and newly colonizing species were largely unknown. Rosenfeld and Raeburn (2009) emphasize the high degree of uncertainty associated with channel design for enhanced fish productivity, stating the following:

> …despite the enormous quantity of research on stream rearing salmonids and their habitat associations, stream ecologists still lack a definitive understanding of the relationship between channel structure, prey production and habitat capacity for drift-feeding fishes. (Rosenfeld and Raeburn 2009: Page 581)

Several commenters proposed that enhanced or increased connectivity of off-channel habitats or habitats above waterfalls could provide fish access to the currently underutilized or inaccessible habitat. This comment presumes that currently disconnected habitats would provide suitable mitigation sites. Based on the above, multiple criteria would have to be met, and numerous assumptions would have to be validated for these sites to qualify as effective mitigation sites. Given the examples of the challenges of connectivity management, use of fishways at waterfalls, and engineered connections to off-channel habitats there is a great deal of uncertainty regarding the efficacy and sustainability of such techniques as compensatory mitigation in the affected watersheds. Further, there also appears to be a lack of opportunities to implement such techniques. When evaluating what compensation measures could reduce the severity of the adverse effects estimated for the 2020 Mine Plan in the Koktuli River watershed,[5] PLP ruled out all other potential measures aside from preservation stating that "[r]estoration, establishment, or enhancement projects within the identified watershed are not plentiful enough in size or scale to mitigate for the identified acreage of direct and indirect impacts to be mitigated" (PLP 2020c).

3.1.1.2 Increase Habitat Quality

EPA received comments about enhancing habitat quality. Addition of large structural elements, such as wood and boulders to streams, has been a common stream habitat rehabilitation approach in locations where stream habitats have been extensively simplified by mining, logging, and associated timber transportation, or other disturbances (Roni et al. 2008). The goals of large-structure additions are typically to create increased hydraulic and structural complexity and improve local-scale habitat conditions for fish in streams that are otherwise lacking in rearing or spawning microhabitats. Properly engineered structural additions to channels can increase hydraulic diversity, habitat complexity, and retention of substrates and organic materials in channels. However, benefits for fish can be highly variable and context-dependent (Roni 2019) and can be difficult to quantify (Richer et al. 2022, Rogers et al. 2022). The unpredictability of beneficial biotic responses to stream structural enhancements is at odds with perceptions by managers whose evaluations tend to be overtly positive—but usually based on

[5] The most severe impacts of the 2020 Mine Plan are concentrated in the SFK and NFK watersheds, which are a part of the Koktuli River watershed.

qualitative opinion rather than scientific observation (Jähnig et al. 2011). In addition, improperly sited or engineered structural additions can fail to achieve desired effects or have adverse, unanticipated consequences (e.g., via structural failure or scour and fill of sensitive non-target habitats (Frissell and Nawa 1992), highlighting the need for appropriate design (Kondolf et al. 2007).

Commenters proposed that the quality of stream habitats in the project area could be enhanced by increasing habitat complexity through the addition of boulders or large wood to existing off-channel habitats. Off-channel habitats can provide important low-velocity rearing habitats for juvenile salmon and other native fishes. Floodplain-complex habitats including beaver ponds, side channels, oxbow channels, and alcoves provide hydraulic diversity that can be important for fishes in variable flows (Amoros and Bornette 2002, Rosenfeld et al. 2008). Beavers are a major player in the creation and maintenance of these habitats in the study area (PLP 2011: Appendix 15.1D), as has been noted elsewhere (Pollock et al. 2003, Rosell et al. 2005). Off-channel habitats also provide important foraging environments, and can be thermally diverse, offering opportunities for thermoregulation or enhanced bioenergetic efficiency (Giannico and Hinch 2003). Off-channel habitats are relatively frequent and locally abundant in area streams and rivers, particularly in lower-gradient, unconstrained valley settings and at tributary confluences (e.g., PLP 2011: Figure 15.1-15). PLP's EBD, Appendix 15.1D (PLP 2011) contains an assessment of the natural fluvial processes creating and maintaining off-channel habitats and their quality, quantity, and function in the SFK, NFK, and UTC watersheds, including mechanisms of connectivity to the mainstem channels. The EBD (PLP 2011) provides background information that is useful for evaluating the potential effectiveness of off-channel habitat modification.

Commenters proposed that off-channel habitats could also be improved by engineered modifications to the depth, shoreline development ratio, and configuration of off-channel habitats to create better overwintering habitat for juvenile salmon. The degree to which existing habitats could be enhanced to improve survival of juvenile salmon as proposed by commenters, will depend on several considerations, including an evaluation of factors known to influence the utilization, survival, and growth within these habitats. These considerations are discussed below.

Off-channel habitats surveyed by PLP and other investigators reveal that patterns of occupancy and density are high but variable among off-channel habitats (PLP 2011: Appendix 15.1D). Some of the highest densities observed were within off-channel habitats, such as side channels and alcoves, but some "isolated" pools held fish (PLP 2011: Appendix 15.1D). This variability could reflect variation in suitability, access, or other characteristics of individual off-channel habitats. Juvenile salmonids require a diverse suite of resources to meet habitat requirements—cover and visual isolation provided by habitat complexity is one such resource. However, other critical resources include food, space, and suitable temperatures and water chemistry (Quinn 2018). Habitat configuration within constructed side-channel habitats can also strongly influence density, size, and growth of juvenile salmonids (Rosenfeld and Raeburn 2009). Giannico and Hinch (2003) in experimental treatments in side channels in British Columbia found that wood additions were beneficial to Coho Salmon growth and survival in surface–water-fed side channels, but not in groundwater-fed channels. They attributed this effect to

differences in foraging strategy and bioenergetics of the juvenile Coho Salmon overwintering in the channels. Additions of wood had no effect, or even possibly a detrimental effect, on Coho Salmon survival in groundwater-fed side channels. These findings highlight the importance of understanding the ecology, bioenergetics, and behavior of the species and life histories present within habitats that may be quite diverse with regard to hydrology and geomorphology.

It is not clear from current data that adding complexity would address any limiting factor within existing off-channel habitats, or that additions of boulders and wood would enhance salmonid abundance or survival. Placement of structures (e.g., boulders, large wood) within stream channels could also have potential adverse consequences, including unanticipated shifts in hydraulic conditions that lead to bank erosion or loss of other desirable habitat features. Sustainability of off-channel habitat modifications is also in question. As stated in the EBD, off-channel habitats are a product of a dynamic floodplain environment and ". . . are continually being created and destroyed" (PLP 2011: Appendix 15.1D; page 2). Maintenance of engineered structures or altered morphologies of such habitats over the long term would be a challenging task (Tullos et al. 2021). Observations from the EBD suggest that beavers are already providing desired complexity:

> . . . habitat mapping from this off-channel study shows that the beaver ponds contain extensive and diverse habitats and dominate the active valley floor" and "…these off-channel habitats provide a critical habitat component of freshwater rearing of Coho Salmon, and to a lesser extent, other anadromous and resident species. (PLP 2011: Appendix 15.1D: Page 14)

3.1.1.3 Increase Habitat Quantity

EPA received comments about increasing habitat quantity. The creation of spawning channels and off-channel habitats has been proposed as a means to compensate for lost salmon spawning and rearing areas. The intent of a constructed spawning channel is to simulate a natural salmon stream by regulating flow, gravel size, and spawner density (Hilborn 1992). Off-channel habitats may be enlarged or modified to alter habitat conditions and capacities for rearing juvenile salmonids. Examples include the many spawning channels (Bonnell 1991) and off-channel habitats (Cooperman 2006) enhanced or created in British Columbia and off-channel ponds rehabilitated by the City of Seattle (Hall and Wissmar 2004).

Off-channel spawning and rearing habitats can be advantageous to salmon populations by providing diverse hydraulic and habitat characteristics. Redds constructed in these habitats may be less susceptible to scour compared to main channel habitats due to flow stability provided by their hyporheic or groundwater sources (Hall and Wissmar 2004). Moderated thermal regimes can provide benefits for growth and survival for overwintering juveniles (Giannico and Hinch 2003). Morley et al. (2005) compared 11 constructed off-channel habitats to naturally occurring paired reference side channels and found that both natural and constructed off-channel habitats supported high densities of juvenile salmonids in both winter and summer. Although numerous studies have documented short-term or localized benefits of constructed off-channel habitats, ascertaining population-level effects is much more difficult (Ogston et al. 2015). Any additional fry produced by spawning channels (if successful) would require additional suitable habitat for juvenile rearing and subsequent life stages in order to have a net positive effect on populations. In a notable study, Ogston et al. (2015) tracked

production of Coho Salmon smolts from rehabilitated floodplain habitats that had been extensively modified by logging and observed a significant population-level increase in smolts. Hilborn (1992) indicates that success, measured by increased production of adult fish from such channels, is unpredictable and generally unmonitored. A notable exception is the study by Sheng et al. (1990), which documented 2- to 8-fold increases in recruitment of Coho Salmon spawner production from groundwater-fed off-channel habitats. Sheng et al. (1990) stated that effectiveness would be greatest in systems that currently lack adequate overwinter refuges. As with any rehabilitation strategy, population responses will depend on whether factors actually limiting production are addressed (Gibeau et al. 2020). Additional research and monitoring would be important to quantify factors currently limiting production within project area watersheds.

Replacing destroyed salmon habitats with new constructed channels is also not a simple task. Factors for consideration in designing and implementing off-channel habitat development are outlined in Lister and Finnigan (1997), and include evaluation of species and life stages present, current habitat conditions, and factors limiting capacity or productivity (Roni et al. 2008). Research indicates that channels fed by hyporheic flow or groundwater may be most effective for creating suitable spawning and rearing habitats (Lister and Finnigan 1997). Near-stream excavation and compaction associated with channel construction can alter groundwater flowpaths, so designing projects to protect current function and groundwater connectivity is important.

Numerous researchers have emphasized that replacing lost habitats is not merely a process of providing habitat structure (Lake et al. 2007). Effective replacement of function also requires establishment of appropriate food web structure and productivity to support the food supply for fish—in essence, an entire ecosystem, including a full suite of organisms such as bacteria, algae, and invertebrates—needs to be in place for a constructed channel to begin to perform some of the same functions of a destroyed stream (Palmer et al. 2010, Bellmore et al. 2017). Quigley and Harper (2006b), in a review of stream rehabilitation projects, concluded "the ability to replicate ecosystem function is clearly limited."

There is some history of using constructed spawning channels to mitigate for the impacts of various development projects on fish, based on the premise that they would provide additional spawning habitat and produce more fry, which would presumably result in more adult fish returning (Hilborn 1992). Off-channel rearing habitats have also been used to create additional overwintering habitats in Pacific Northwest rivers (Roni et al. 2006), and spawning channels have also been shown to provide suitable overwintering habitats for juvenile Coho Salmon (Sheng et al. 1990). Reliance on spawning channels for fishery enhancement may also introduce unintended adverse consequences. Enhancement of Sockeye Salmon via use of spawning channels in British Columbia's Skeena River has been accompanied by the erosion of local diversity and homogenization of life history traits, leading to possible losses in the spatial availability of salmon harvests to indigenous fisheries and local ecosystems (Price et al. 2021). Constructed spawning channels, particularly those dependent on surface flow, may also require annual maintenance and cleaning (Hilborn 1992), and salmon using them can be prone to disease outbreaks (Mulcahy et al. 1982). Off-channel habitats to mainstems are also extremely difficult

to engineer in a way that can self-sustain in the face of a dynamic fluvial environment. Alluvial channels frequently shift (Amoros and Bornette 2002), and beavers are highly effective ecosystem engineers whose activities are constantly re-arranging floodplain channels and creating new dams (Pollock et al. 2003), including within engineered channels and culverts (Cooperman 2006).

In light of their uncertain track record, it does not appear that constructed spawning channels and engineered connections of off-channel habitats would provide reliable and sustainable fish habitat in the Bristol Bay region.

3.1.1.4 Manage Water Quantity

Two commenters suggested a variety of techniques to manipulate water quantities within the SFK, NFK, and UTC watersheds to improve fish productivity. Possible techniques for accomplishing this include flow management, flow augmentation, and flow pump-back.

3.1.1.4.1 Direct Excess On-site Water

Commenters suggested that fish habitat productivity could be improved through careful water management at the mine site, including the storage and strategic delivery of excess water to streams and aquifers to maintain or enhance flow and/or thermal regimes in the receiving streams. Delivering such flows via groundwater (i.e., by using wastewater treatment plant (WTP) discharges to "recharge and surcharge groundwater aquifers") was identified as a preferred approach; commenters argued doing so would both render the measure less prone to operational anomalies at the WTP and better mimic current natural flow patterns, thereby attenuating potential adverse effects related to discharge volume and temperature. Ideally, flow, temperature, and habitat modeling would inform the design and operation of flow management to optimize species and habitat benefits, for example, by providing water at specific times to locations where low flow currently limits fish productivity.

Manipulation of surface flows at another mine in Alaska—Red Dog, in the northwest part of the state—has resulted in an increase in fish (Arctic Grayling and Dolly Varden) use of the downstream creek (Weber-Scannell 2005, Ott 2004). The circumstances at Red Dog, however, differ from those in the SFK, NFK, and UTC area. As described in Weber-Scannell (2005), the near complete absence of fish in Red Dog Creek prior to implementation of the water management techniques was the direct result of water quality, not quantity, as the stream periodically experienced toxic levels of metals that occurred naturally as it flowed through and downslope of the exposed ore body. Furthermore, the Red Dog water management system primarily involves point-to-point diversion or transfer of surface, rather than groundwater, both around the ore body and from tributaries upstream of the mine. Utilization of managed aquifer surcharge or recharge to manage streamflows (e.g., Van Kirk et al. 2020) involves significant complexities that may require spatially distributed numerical modeling and would still be subject to considerable uncertainty (Ronayne et al. 2017), particularly in hydrologically complex areas like the Pebble deposit site.

Given that most streams in the area support multiple salmonid species and life stages, with differing habitat needs at different times, designing and managing a water delivery system to overcome limiting factors for one or more species without adversely affecting others would be a significant challenge. Given the complexity of the surface-groundwater connectivity in the watersheds draining the Pebble deposit, ensuring that discharges to groundwater actually reached the target habitat at the intended time would, perhaps, be the most difficult task. Quigley and Harper (2006b), in a review of stream rehabilitation projects, concluded "the ability to replicate ecosystem function is clearly limited."

This challenge could be easier to overcome where habitat limitations occurred only as a result of mine development, assuming pre-project modeling and verification accurately identified groundwater flow paths to those areas. It is important to note, however, that even if such actions appeared to be feasible, they likely would be required to avoid or minimize the adverse impacts of flow reduction due to mine development, rather than to compensate for unavoidable habitat losses.

If it were an overall enhancement to pre-existing habitat, using WTP discharges to groundwater to address natural limitation factors could be a form of compensatory mitigation. For example, PLP (2011) points out that productivity may be limited by the existence of "losing" reaches along the SFK mainstem and intermittent or ephemeral tributaries to both the SFK and NFK. Altering the natural flow regimes at such sites, however, could have unintended consequences on the local ecosystem and species assemblages (Poff et al. 1997). Moreover, "enhancing" these habitats through a WTP-sourced groundwater flow delivery system would be even more challenging than managing flow to avoid or minimize impacts to already productive habitat, because it would require "improving" the natural flow delivery system that currently results in the periodic drying or low flows. Given that aquifer recharge for streamflow management is a highly experimental approach to enhancing fish productivity, particularly in a natural stream system there is a great deal of uncertainty regarding the efficacy and sustainability of this technique as compensatory mitigation in the affected watersheds.

3.1.1.4.2 Augment Flows

Another means suggested for maintaining or increasing habitat productivity downstream of the mine site is to increase flow volume into specific streams by creating new sources of surface flow or groundwater recharge, specifically from impoundments or ice fields. EPA is unaware of any documented successful compensatory mitigation efforts to create impoundments or ice fields for the benefit of salmonids. If there were potential locations for impoundments to manage flow in stream reaches identified as having "sub-optimal" flow, logistical and environmental issues decrease the likely efficacy and sustainability of such an approach. Manipulating streamflows in particular watersheds would require diverting water from other basins or capturing water during peak flows for subsequent release at other times, with the concomitant engineering, construction, and maintenance challenges. Doing so would create additional adverse impacts from the construction of infrastructure and would be subject to modeling and perpetual management sufficient to ensure that water withdrawals from the "donor" watershed or from other times of the year would not adversely affect fish habitat and populations in the donor watershed or the watershed's downstream waters. These concerns are in addition to those

commonly associated with impoundments, such as alteration of flow, thermal, and sediment transport regimes.

Creating ice fields to increase the total volume of water available to a stream would also require water diversion, with the same challenges and concerns related to building and maintaining system infrastructure and reducing water volumes in the source watershed. Using ice fields to change the timing of water availability would create issues related to managing the melt to produce stream flow at the intended time (i.e., late summer or late winter low-flow periods). Moreover, because aquatic organisms supported by a particular waterbody typically have evolved specific life history, behavioral, and morphological traits consistent with the characteristics of that waterbody's natural flow regime, local populations are inherently vulnerable to flow modification (Lytle and Poff 2004). Any use of ice fields would face the potentially substantial challenges of the effects of climate change on ice production and preservation. Given the logistical and environmental issues associated with this technique and the lack of evidence of its use to benefit salmonids, it does not appear to be an effective or sustainable approach to compensatory mitigation in the affected watersheds.

3.1.1.4.3 Pump Water Upstream

Another option suggested for making flow in some stream reaches more persistent is to pump groundwater or surface water from a down-gradient site upstream to either a direct release point or a recharge area. This technique has been used for fish habitat restoration at sites in the continental United States, for example, the Umatilla River in Oregon (Bronson and Duke 2005), the Lower Owens River in California (LADWP 2013), and Muddy Creek in Colorado (AECOM et al. 2012). However, EPA is unaware of any documentation addressing its efficacy in increasing salmonid productivity.

Even if potential source sites with sufficient water could be identified, this technique would require substantial disturbance and additional environmental impacts associated with the construction of tens of kilometers of water pipeline, power infrastructure, and access, along with maintenance of those facilities in perpetuity. It would also entail active management to ensure that releases occur at appropriate times to increase the persistence of flow in target streams without otherwise adversely affecting their hydrographs or habitat. Such management would be another aspect of the approach that would be perpetual. In total, this technique would involve a great deal of uncertainty with regard to both efficacy and sustainability, making it a questionable mechanism for providing compensatory mitigation.

3.1.1.5 Manipulate Water Quality

Two commenters suggested that alteration of stream water chemistry would improve fish production in the SFK, NFK, and UTC. They suggested increasing two groups of water chemistry parameters: basic parameters such as alkalinity, hardness, and total dissolved solids, and nutrients such as nitrogen (N) and phosphorous (P). This argument suggests that low concentrations of basic parameters or nutrients limit algae production, thus, limiting aquatic macroinvertebrate production and habitat complexity. This, in turn, can reduce overall fish production, reduce individual fish growth rates, or result in fish movements away from low production areas.

3.1.1.5.1 Increase Levels of Alkalinity, Hardness, and Total Dissolved Solids

PLP suggested in its 2014 comments that current levels of alkalinity, hardness, and total dissolved solids (TDS) in the SFK, NFK, and UTC are suboptimal for fish production and could be manipulated to improve fish production. PLP proposes "that streams with higher concentrations of total alkalinity, hardness, and total dissolved solids, assuming no nutrient limitations due to low concentration of nitrogen or phosphorus, produce a higher biomass per unit area than areas with lower concentrations" (PLP 2014, Exhibit 6). However, PLP does not propose any actual mechanisms for fish habitat compensation via increases in alkalinity, hardness, or TDS nor does it state its basis for assuming that N and P are not limiting.

PLP proposed increasing levels of alkalinity, hardness, and TDS in streams as a compensation proposal in its comments on the draft BBA (NDM 2013, Attachment D). In these comments, PLP refers to a number of field studies of streams. The cited studies of stream manipulations that raise alkalinity, hardness, or TDS are studies of the mitigation of acid mine drainage or of streams acidified by acid deposition (Gunn and Keller 1984, Hasselrot and Hultberg 1984, Rosseland and Skogheim 1984, Zurbuch 1984, Gagen et al. 1989, Lacroix 1992, Clayton et al. 1998, McClurg et al. 2007). The addition of limestone or dolomite often increases the production of acidic streams, and alkalinity, hardness, and TDS also increase, but the coincidence is not necessarily causal. It is more likely that the improvement is due to reduced acidity or reduced dissolved metal concentrations, not to increased alkalinity, hardness, or TDS per se. Other studies address the differences in the natural ability of streams to buffer natural or anthropogenic acids. Streams with acidic inputs and high buffering capacity may have higher productivity, as well as high alkalinity, hardness, and TDS. Other studies cited were not explicitly acidified sites, but it was not clear what role, if any, alkalinity, hardness, or TDS played in reported differences in productivity among those streams. Some of the studies are confounded by differences in habitat, macronutrients, or other factors. Others suffer from pseudo-replication or low replication.

Further, PLP's comments (NDM 2013, Attachment D) do not support that such measures would be effective. For example, it cites Scarnecchia and Bergersen (1987) as supporting the importance of alkalinity, hardness, and TDS at the Pebble site (NDM 2013, Attachment D, Section 3.4.2.1). However, Scarnecchia and Bergersen concluded the opposite. They found that most of the variance in productivity and biomass was associated with elevation and the three chemical parameters were correlated with elevation: "The overall weakness (despite statistical significance) of the correlations of chemical factors with production suggested to us that physical factors strongly influence production in these streams. Elevation, percentage of zero-velocity stations, and substrate diversity were the three most effective combinations of variables for explaining variation in production."

Given the lack of a mechanism by which any of the three aggregated parameters would increase productivity in the absence of acidity or high metal concentrations and inherent problems in the studies, the causal nature of the reported field relationships is questionable. In any case, their relevance to compensatory mitigation of the Pebble site has not been demonstrated.

The potential for unintended adverse consequences if alkalinity, hardness, or TDS are raised without an understanding of the mechanisms of action and of the chemistry and biology of the receiving streams is illustrated by studies that show impairment of stream communities in response to elevating one or more of those parameters. In particular, the addition of limestone or dolomite to streams to mitigate acid drainage and the filling of valleys with carbonaceous rock from mining have raised hardness, alkalinity and TDS/conductivity, which have been shown to cause adverse and persistent effects on stream invertebrate and fish communities (Weber-Scannell and Duffy 2007, Pond et al. 2008, Bernhardt and Palmer 2011, Cormier et al. 2013a, Cormier et al. 2013b, Hopkins et al. 2013, Hitt and Chambers 2014, Morris et al. 2019).

3.1.1.5.2 Increase Levels of Nitrogen and/or Phosphorus

Commenters have also suggested that water quality could be manipulated by altering stream water chemistry to increase levels of N and P where they are individually or co-limiting.

The commenters make recommendations about how to consider these factors when developing mitigation in the SFK, NFK, and UTC. They suggest that the spatial distribution could focus on existing or newly created side channels, sloughs, beaver ponds, alcoves, or, if necessary, the main channels at 10-km intervals. They suggest several possible temporal distribution options, such as adding the nutrients only during the growing season, potentially earlier, or all winter in open-water locations where biological production continues year-round. They further indicate that the key considerations are access cost and maintenance requirements. The commenters note that there are several types of nutrient delivery methods: liquid fertilizer, slow-release fertilizer, and nutrient analogs (which are essentially slow-release pellets of processed fish).

As support for their conclusion that lake and stream fertilization represent “demonstrably successful mitigation techniques” for the SFK, NFK, and UTC, the commenters cite papers summarizing experiments and case studies, as well as references to several management programs in the United States, Canada, and northern Europe. These studies have examined the use of increased levels of inorganic N and P, or fish carcasses, to improve ecosystem productivity and/or fish production.

The commenters assert that current levels of N and P in the SFK, NFK, and UTC are suboptimal for fish production stating that benefits of fertilizing oligotrophic waters to stimulate fish production have been demonstrated in many venues. Although numerous studies show an effect at one or more trophic levels in response to fertilization, these studies are insufficient for drawing conclusions regarding the long-term effectiveness of nutrient application to streams in the SFK, NFK, and UTC watersheds because they lack scientific controls or have not been replicated, do not account for potential confounding factors, were conducted in very different ecosystems, and/or only evaluated short-term effects. These differences are discussed in the following paragraphs.

Commenters provided examples of experiments and studies aimed at increasing primary productivity and theoretically salmon productivity. These studies assume that nutrients are the limiting factor preventing increased salmon productivity, but that is not necessarily the case (Collins et al 2015).

Paleolimnetic studies in Alaska indicate nutrient inputs are not always tied to higher primary productivity or salmon productivity (Chen et al. 2011). Wipfli and Baxter (2010) found that most fish consume food from external or very distant sources, including from marine systems borne by adult salmon, from fishless headwaters that transport prey to downstream fish, and from riparian vegetation and associated habitats. An increase in food via nutrients may not overcome other limiting factors, such as habitat availability or interspecies competition.

Most studies on stream and lake fertilization to increase productivity are short term in duration and conducted in ecosystems with important differences from Bristol Bay (e.g., Perrin et al. 1987, Raastad et al. 1993, Wipfli et al. 1998, Slaney et al. 2003). Many of the studies have been conducted in lakes (e.g., Bradford et al. 2000, Kyle 1994), which have different ecosystem dynamics from streams. Furthermore, factors that limit populations in one habitat or time period may be different than in another (Collins et al. 2015). Almost all of the stream studies are conducted in locations where salmon populations have been negatively affected; therefore, the increased production is aimed at restoration, not enhancement, of an existing healthy population.

Most studies are conducted between one and five years in duration, and a spike in productivity has been seen in a number of these short-term studies. For example, the studies conducted at the Keogh and Salmon Rivers (Ward et al. 2003, Slaney et al. 2003) examined the effect of nutrient supplement in the form of salmon carcasses and inorganic N and P, respectively, in two coastal river systems for a period of three years. Additionally, most studies quantify responses at the individual level, which may not translate to an increase at the population level (Collins et al. 2015).

While a short-term spike in productivity is common, long-term studies call into question whether the trend will be sustained over longer periods. Several papers cite results from the early years of the longest-running study on stream fertilization located in the pristine Kuparuk River on the North Slope of Alaska. This study raises concerns about using fertilization other than as an interim restorative measure. While commenters cite a study capturing the increased size and growth rates of Arctic Grayling during the first seven years of the study (Deegan and Peterson 1992), a subsequent paper documenting conditions after 16 years found that persistent increased levels of N and P can result in dramatic ecosystem shifts (Slavik et al. 2004). This long-term ecological research on the North Slope of Alaska examined the effect of P input into P-limited streams, finding an increase in production for some species at all trophic levels over the first few years. These results are similar to the studies finding improved fish productivity in predominantly degraded systems cited extensively by commenters. However, after approximately eight years of fertilization, a dramatic rise in moss (photos A and B) changed ecosystem structure, affecting food and shelter availability (Slavik et al. 2004). Despite higher insect biomass in the fertilized area during this period, there were no significant differences in fish growth rates between the fertilized reach and the reference reach. The decrease in fish productivity was thought to result from the effects of moss on preferred insect prey (Slavik et al. 2004, Gough et al. 2016). Following cessation of nutrient enrichment, it took eight years of recovery to approach reference levels, after storms had

scoured most remnant moss in the recovering reach, demonstrating that even at low concentrations, sustained nutrient enrichment can have "dramatic and persistent consequences" (Benstead et al. 2007).

Photos showing the difference in bottom coverage between the diatom state (Photo A, left) and the fertilized moss state (Photo B, right). Used with permission (Slavik et al. 2004).

Slavik et al. (2004) conclude that "[a]dditional long-term whole stream fertilization studies are needed to better understand the delayed stream ecosystem responses to nutrient enrichment. Even studies of two to eight years in duration may be poor predictors of the long-term responses to added nutrients." This conclusion is echoed in the most recent (2019) *Long Term Ecological Research Network Decadal Review Self Study* (Groffman et al. 2019), which is a collection of papers reflecting study and experimentation at diverse sites ranging from arctic and alpine tundra to grasslands, forests, streams, wetlands, and lakes. In the paper addressing nutrient supply effects on ecosystems, the authors state, "Long term observations and experiments at LTER sites have shown that short term patterns may have little bearing on the ultimate direction and magnitude of nutrient effects, which can play out over many decades" (Groffman et al. 2019: Page 23). The risks of long-term fertilization would also play out in the context of global climate change, which is predicted to cause a release of phosphorous into streams from melting permafrost (Hobbie et al. 1999), adding yet another layer to the unknowns.

In another study, long-term nutrient enrichment produced an unanticipated trophic decoupling whereby enrichment continued to stimulate primary consumer production without a similar increase in predator fish (Davis et al. 2010). The majority of the increased ecosystem productivity was confined to lower trophic levels because the long-term enrichment primarily stimulated primary consumers that were relatively resistant to predation. Based on these results, the authors concluded that "even in ecosystems where energy flow is predicted to be relatively efficient, nutrient enrichment may still increase the production of non-target taxa (e.g., predator or grazer resistant prey), decrease the production of higher trophic levels, or lead to unintended consequences that may compromise the productivity of freshwater ecosystems" (Davis et al. 2010).

These unanticipated results raise important questions about the potential consequences of long-term nutrient supplementations. They also underscore the unpredictability of nutrient additions on the food web, and the greater likelihood of unintended consequences as the effects ripple through complex interactions between species. These implications are relevant considerations for potential long-term

mitigation, which would be necessary for the SFK, NFK, and UTC. If long-term nutrient addition were to cause an ecosystem shift at lower trophic levels in the SFK, NFK, and UTC, effects on higher trophic levels including the productivity of salmon and other target fish species are unknown.

Studies examining the relationship between salmon carcasses and productivity at various trophic levels are another active area of investigation. Some research provides evidence that carcasses are superior to inorganic nutrient amendments for sustaining and restoring stream productivity, including fish production, potentially because inorganic nutrients lack biochemicals and macromolecules that are utilized directly by consumers (Wipfli et al. 2010, Martin et al. 2010, Heintz et al. 2010). Others have found the effects of carcasses can be transient, localized, and variable with no increase in fish growth (Cram et al. 2011). Few studies have documented the long-term impacts of carcass addition, and there are many remaining gaps in understanding the efficacy of this method of potentially improving salmon productivity. In addition, a number of authors express concern about the potential for the spread of toxins and pathogens when carcasses are used as the supplemental nutrient source (Compton et al. 2006).

Authors of many of these studies state that the application of their results are relevant and appropriate for salmonid restoration in streams or lakes with depressed numbers (e.g., Larkin and Slaney 2011). The authors do not describe their results as informing methods to manipulate existing unaltered wild systems to further augment salmon production. Although some commenters draw heavily from Ashley and Stockner (2003) to support their recommendation to use this as a method of mitigation in the SFK, NFK, and UTC watersheds, the authors of that study state the following:

> The goal of stream and lake enrichment is to rebuild salmonid escapement to historical levels via temporary supplementations of limiting nutrients using organic and/or inorganic formulations. Stream and lake enrichment should not be used as a 'techno-fix' to perpetuate the existing mismanagement of salmonids when there is any possibility of re-establishing self-sustaining wild populations through harvest reductions and restoration of salmonid habitat. Therefore, fertilization should be viewed as an interim restorative measure that is most effective if all components of ecosystem recovery and key external factors (e.g. overfishing) are cooperatively achieved and coordinated. This paper reviews some of the technical and more applied aspects of stream, river, and lake enrichment as currently practiced in British Columbia and elsewhere. As a caveat, the discussion assumes that salmonid stock status of candidate lakes and streams has been quantified and classified as significantly depressed and that additional limiting factors (e.g. habitat/water quality and quantity) have been addressed and/or incorporated into an integrated basin or lake restoration plan. (Ashley and Stockner 2003: Page 246)

There are still many gaps in understanding the role of nutrients in fish productivity, so there is much that is not known about whether nutrient addition can be a successful method to increase fish productivity especially in the long term. Furthermore, much of the existing literature on which commenters base their assertions rests on several untested assumptions (Collins et al. 2015).

Setting aside questions of scientific efficacy and applicability, there are also numerous practical challenges inherent in nutrient addition as a potential mitigation method. Conducting a long-term management protocol in remote waterways subject to extreme weather changes necessarily requires careful monitoring of water chemistry, as well as other ecosystem parameters and precise application of

nutrients, which calls into question the sustainability of altering stream water chemistry to improve the fish production.

At this time, there are no scientific studies showing how an increase in nutrients resulting in increased salmon productivity can be reliably achieved on a long-term basis in the SFK, NFK, and UTC watersheds or the larger Bristol Bay ecosystem without risk to the region's existing robust populations. Just as for the addition of non-nutrients, such as limestone, manipulating stream chemistry in this largely unaltered ecosystem through the addition of N and P would be a challenging and difficult experiment with many negative outcomes being possible.

3.1.2 Other Potential Compensation Measures Suggested within the Nushagak and Kvichak River Watersheds

As noted above, if practicable or appropriate opportunities to provide compensation within the SFK, NFK, or UTC watersheds are non-existent or limited, it may be appropriate in certain circumstances to explore options in adjoining watersheds. For example, there are a few scattered degraded sites in more distant portions of the Nushagak and Kvichak River watersheds that could potentially benefit from restoration or enhancement. This section discusses specific suggestions for other potential compensation measures within the Nushagak and Kvichak River watersheds that were provided in the public and peer review comments on the BBA and in response to the 2014 Proposed Determination.

3.1.2.1 Remediate Old Mine Sites

The U.S. Geological Survey identifies four small mine sites within the Nushagak and Kvichak River watersheds: Red Top (in the Wood River drainage), Bonanza Creek (a Mulchatna River tributary), Synneva or Scynneva Creek (a Bonanza Creek tributary), and Portage Creek (in the Lake Clark drainage) (USGS 2008, 2012). These sites could provide opportunities for performing ecological restoration or enhancement. However, due to their relatively small size and distant location, it is unlikely that these sites could provide sufficient restored or enhanced acreage or ecological function to reduce the adverse effects of the 2020 Mine Plan to an acceptable level. Further, some mitigation measures have already occurred at these mines; for example, Alaska Department of Environmental Conservation (ADEC) determined the cleanup of the Red Top mercury retort site to be complete in 2012 (ADEC 2012). Resolution of liability and contamination issues at these old mines would be necessary before they could serve as compensatory mitigation sites for other projects. In its comments on the 2014 Proposed Determination, PLP rejected this as a potential compensation measure, in part, due to concerns regarding the resolution of these kinds of liability issues (PLP 2014: Exhibit 2).

3.1.2.2 Remove Roads

Another potential type of restoration within the Nushagak and Kvichak River watersheds is the removal of existing or abandoned roads. As described in detail in EPA 2014, Appendix G, roads have persistent, multifaceted impacts on ecosystems and can strongly affect water quality and fish habitat. Common long-term impacts from roads include (1) permanent loss of natural habitat; (2) increased surface runoff

and reduced groundwater flow; (3) channelization or structural simplification of streams and hydrologic connectivity; (4) persistent changes in the chemical composition of water and soil; (5) disruption of movements of animals, including fishes and other freshwater species; (6) aerial transport of pollutants via road dust; and (7) disruption of near-surface groundwater processes, including interception or re-routing of hyporheic flows, and conversion of subsurface slope groundwater to surface flows (Trombulak and Frissell 2000, Forman 2004). Road removal, thus, could facilitate not only the reestablishment of former wetlands and stream channels, but also the enhancement of nearby aquatic resources currently degraded by the road(s).

Commenters did not offer specific suggestions for potential road-removal sites. As EPA 2014 Appendix G highlights, the Nushagak and Kvichak River watersheds are almost entirely roadless areas (EPA 2014, Appendix G, Figure 1). Further, it is unlikely that local communities would support removal of any segments of the few existing roads in the watersheds. Thus, it appears there are very few, if any, viable opportunities to provide environmental benefits through road removal.

3.1.2.3 Retrofit Road Stream Crossings

Another potential type of enhancement within the Nushagak and Kvichak River watersheds is to retrofit existing road stream crossings to improve fish passage through these human-made features. Stream crossings can adversely affect spawning, rearing (Sheer and Steel 2006, Davis and Davis 2011), and refuge habitats (Price et al. 2010), as well as reduce genetic diversity (Wofford et al. 2005, Neville et al. 2009). These changes can, in turn, reduce long-term sustainability of salmon populations (Hilborn et al. 2003, Schindler et al. 2010). Blockage or inhibition of fish passage is a well-documented problem commonly associated with declines in salmon and other fish populations in many regions of the United States (Nehlsen et al. 1991, Bates et al. 2003), including Alaska (ADF&G 2022).

Removing and replacing crossings that serve as barriers to fishes could improve fish passage and re-open currently inaccessible habitat. However, as noted in Section 3.1.2.2, the Nushagak and Kvichak River watersheds are almost entirely roadless areas and, thus, likely offer few, if any, viable opportunities to provide the extent of environmental benefits necessary to reduce the adverse effects of the 2020 Mine Plan to an acceptable level. Further, prior to concluding that any effort to retrofit existing stream crossings would be appropriate compensatory mitigation, it would first be necessary to determine that no other party has responsibility for the maintenance of fish passage at those stream crossings (e.g., through the terms or conditions of a CWA Section 404 permit that authorized the crossing). After initially proposing this as a potential compensation measure, in its comments on the 2014 Proposed Determination, PLP rejected this measure due to “the long term liability involved as PLP would be responsible for effectiveness in perpetuity, possible requiring monitoring and maintenance (including repair and replacement)” (PLP 2014: Exhibit 2).

3.1.2.4 Construct Hatcheries

One commenter referenced the potential use of hatcheries as a compensation measure. Such a proposal could be very problematic, particularly in the Bristol Bay watershed, where the current salmon

population is entirely wild. There are several concerns over the introduction of hatchery-produced salmon to the Bristol Bay watershed.

Many of the potential risks associated with fish hatcheries concern reductions in fitness, growth, health, and productivity that result from decreases in genetic diversity when hatchery-reared stocks hybridize with wild salmon populations. Hatchery-raised salmon have lower genetic diversity than wild salmon (Christie et al. 2011, Yu et al. 2012). Consequently, when hatchery-raised salmon hybridize with wild salmon, the result can be a more genetically homogenous population, leading to decreases in genetic fitness (Waples 1991). In some cases, wild populations can become genetically swamped by hatchery stocks. Zhivitovsky et al. (2012) found evidence of such swamping in a wild Chum Salmon population in Kurilskiy Bay, Russia, during a two-year period of high rates of escaped hatchery fish. This genetic homogenization is of concern because hatchery-raised fish stocks are considered less genetically "fit" and, therefore, could increase the risk of collapse of salmon fisheries. This concern is supported by Araki et al. (2008); a review of 14 studies that suggests that nonlocal hatchery stocks reproduce very poorly in the wild. The authors of this review also found that wild stocks reproduce better than both hatchery stocks and wild, local fish spawned and reared in hatcheries.

Hatchery fish can also compete directly for food and resources with wild salmon populations in both freshwater and marine environments (Rand et al. 2012a). Ruggerone et al. (2012) examined the effect that Asian hatchery Chum Salmon have had on wild Chum Salmon in Norton Sound, Alaska, since the early 1980s. They found that an increase in adult hatchery Chum Salmon abundance from 10 million to 80 million adult fish led to a 72 percent reduction in the abundance of the wild Chum Salmon population. They also found smaller adult length-at-age, delayed age-at-maturation, and reduced productivity were all associated with greater production of Asian hatchery Chum since 1965 (Ruggerone et al. 2012). In addition to this competition for resources, hatchery-raised subyearling salmon can also prey upon wild subyearling salmon, which tend to be smaller in size (Naman and Sharpe 2012).

Despite extensive efforts to restore federally listed Pacific Northwest salmon populations, these salmon remain imperiled, and hatchery fish stocks may be a contributing stressor (Kostow 2009). Given the exceptional productivity of the wild Bristol Bay salmon population, hatcheries would likely pose greater ecological risks than benefits to this unique and valuable wild salmon population.

3.1.2.5 Stock Fish

Comments also mentioned stocking fish. Because many of the fish used in fish stocking originate in hatcheries, fish stocking raises many of the same concerns as hatcheries and, thus, would also be a problematic form of compensatory mitigation for the Bristol Bay region. Although stocking has been a common practice in other regions, even in previously fishless habitats (e.g., Red Dog Mine, Alaska), a large body of literature describes widespread adverse impacts of such management decisions. Fish stocking throughout western North America and worldwide has affected other fish (Knapp et al. 2001, Townsend 2003), nutrient cycling (Schindler et al. 2001, Eby et al. 2006, Johnson et al. 2010), primary production (Townsend 2003, Cucherousset and Olden 2011), aquatic macroinvertebrates (Dunham et

al. 2004, Pope et al. 2009, Cucherousset and Olden 2011), amphibians (Pilliod and Peterson 2001, Finlay and Vredenberg 2007), and terrestrial species (Epanchin et al. 2010). Although fish stocking has provided limited benefits in certain circumstances, it would appear from the growing body of literature that the ecological costs of fish stocking far outweigh any potential benefits.

3.2 Other Suggested Measures

Commenters also suggested that payments to organizations that support salmon sustainability or investing in various public education, outreach, or research activities designed to promote salmon sustainability could constitute potential compensatory mitigation for impacts on fish and other aquatic resources. Although these initiatives can provide benefits in other contexts, compensatory mitigation for impacts authorized under Section 404 of the CWA can only be provided through purchasing credits from an approved mitigation bank or in-lieu fee program or conducting permittee-responsible compensatory mitigation projects (40 CFR 230.92). One commenter also suggested reducing commercial fishery harvests to compensate for fish losses due to large-scale mining; however, such a measure would also be inconsistent with the definition of compensatory mitigation (40 CFR 230.92).

In its comments on the 2014 Proposed Determination, PLP (2014, Exhibit 2) provides a list of compensation measures that it was not recommending, specifically culvert replacement, contaminated site clean-up, landfill rehabilitation or replacement, and clean-up and restoration of legacy wells. In deciding not to recommend these measures in 2014, PLP notes that "[t]he task to evaluate mitigation actions in the Bristol Bay region included all opportunities available" and that the feasibility of these opportunities was identified as "very expensive, high-risk, low compensatory credit return" and that "[g]enerally, the main limitation to these permittee-responsible mitigation projects is a lack of opportunity for restoration, establishment, and/or enhancement of wetlands within the Bristol Bay region." PLP goes on to state that "[o]ther limitations to these permittee-responsible mitigation projects include liability, cost, monitoring responsibilities in perpetuity, and the lack of infrastructure within the Bristol Bay region to access existing opportunities" (PLP 2014: Exhibit 2).

SECTION 4. EFFECTIVENESS OF COMPENSATION MEASURES AT OFFSETTING IMPACTS ON FISH HABITAT

In North America, 73 percent of fish extinctions are linked to habitat alterations (Miller et al. 1989). Although extensive efforts have been undertaken to create or improve salmon habitat and prevent fishery losses, all U.S. Atlantic salmon populations are endangered (NOAA 2022), 40 percent of Pacific salmon in the lower 48 states are extirpated from historical habitats (NRC 1996), and one-third of remaining populations are threatened or endangered with extinction (Nehlsen et al. 1991, Slaney et al. 1996, Gustafson et al. 2007). Coho and Chinook salmon are the two rarest of North America's five species of Pacific salmon (Healey 1991) and have the greatest number of population extinctions among the five species of Pacific salmon (Nehlsen et al. 1991, Augerot 2005). Approximately one-third of Sockeye Salmon population diversity assessed by Rand et al. (2012b) was considered at risk of extinction or extinct. Of remaining populations categorized as of "least concern," Bristol Bay Sockeye Salmon likely represent the most abundant, diverse Sockeye Salmon populations left in the United States.

Since 1990, a billion dollars has been spent annually on stream and watershed restoration in the United States (Bernhardt et al. 2005). More than 60 percent of the projects completed during this period were associated with salmon and trout habitat restoration efforts in the Pacific Northwest and California (Katz et al. 2007). Despite the proliferation of projects and the significant funds being expended on these efforts, debate continues over the effectiveness of various fish habitat restoration techniques and the cumulative impact of multiple, poorly coordinated restoration actions at watershed or regional scales (Reeves et al. 1991, Chapman 1996, Roni et al. 2002, Kondolf et al. 2008). However, in the Columbia River Basin where billions of dollars have been spent on salmon and steelhead recovery efforts, a 2013 report indicates that some stream rehabilitation techniques, such as fish passage improvements, in-stream wood and rock structures, livestock grazing controls, connection or construction of off-channel habitat, and flow augmentation appear to be leading to fish habitat improvements in this basin where logging, grazing, channelization, irrigation, development of urban areas, and construction and operation of dams have led to extensive historic fish habitat loss and degradation (BPA 2013).

A 2014 review of 434 stream restoration, enhancement, and creation projects conducted to offset impacts to Appalachian streams from surface coal mining authorized by CWA Section 404 permits highlights the uncertain outcomes of stream mitigation projects (Palmer and Hondula 2014). Palmer and Hondula (2014) found that even after five years of monitoring, 97 percent of projects reported suboptimal or marginal habitat; they conclude that stream mitigation projects "are not meeting the objectives of the Clean Water Act to replace lost or degraded streams ecosystems and their functions."

In general, independent evaluations of the effectiveness of fish habitat compensation projects are rare (Harper and Quigley[6] 2005b, Quigley and Harper 2006a, Quigley and Harper 2006b), and consequently the long-term success rates and efficacy of such projects are not well known (DFO 1997, Lister and Bengeyfield 1998, Lange et al. 2001, Quigley and Harper 2006a). A 2008 review of stream habitat rehabilitation studies published worldwide found that "[d]espite locating 345 studies on effectiveness of stream rehabilitation, firm conclusions about many specific techniques were difficult to make because of the limited information provided on physical habitat, water quality, and biota and because of the short duration and limited scope of most published evaluations" (Roni et al. 2005, Roni et al. 2008). Despite these shortcomings, Roni et al. (2008) did find that some techniques, specifically, reconnection of isolated habitats, floodplain rehabilitation, and instream habitat improvement, were proven to be effective under numerous circumstances for improving habitat and increasing local fish abundance.

In its 2014 comments, PLP relies heavily on the findings of Roni et al. (2008) and BPA (2013) to support the following positions.

- The effectiveness of the stream rehabilitation techniques PLP had proposed at that time for use at the Pebble site is unequivocal and "settled science."
- These stream rehabilitation techniques should be expected to effectively rehabilitate streams permanently lost or degraded by mining at the Pebble deposit.
- These stream rehabilitation techniques should also be expected to result in demonstrable improvements in fish habitats in unaltered/undegraded streams that are currently part of an ecosystem that supports some of the world's most productive wild salmon runs.

While PLP ultimately did not propose any of these measures during the CWA Section 404 permit review process (PLP 2020a, 2020c), its application of the findings of Roni et al. (2008) and BPA (2013) is inaccurate or oversimplified for the following reasons.

- Type of restoration is different. The effectiveness of the stream rehabilitation techniques reviewed in these papers is not settled science, and the success of these approaches is highly variable and context-dependent (Roni 2019); can be difficult to quantify (Richer et al. 2022, Rogers et al. 2022); and must address the suite of factors influencing fish populations (water quality, connectivity, hydrology, sediment, etc.).
- Impact is different. A large majority of the stream rehabilitation studies reviewed in these papers were conducted in moderate climates, for streams that had been impacted by forestry, agriculture,

[6] Dr. Jason Quigley, a scientist employed in 2014 by a company working to advance a mine at the Pebble deposit, sent EPA Region 10 a letter dated April 28, 2014, indicating his concern that the BBA cited his work in a manner that is "not fully accurate." EPA notes that the findings and conclusions of Dr. Quigley's earlier studies referenced by the BBA are taken directly from Dr. Quigley's studies. Further, EPA clearly notes in this section that Quigley's earlier studies highlight the need for improvements in compensation science, as well as institutional approaches, such as better project planning, monitoring, and maintenance. Dr. Quigley's letter also notes that compensation success has improved since his earlier studies; however, no examples of such documented success are included in his letter.

roads, or human activities other than mining. The papers were not a review of rehabilitation of streams impacted by mining. Where reviews of mined stream mitigation success have occurred in Appalachia, monitoring revealed that 97 percent of the projects reported suboptimal or marginal habitat (Palmer and Hondula 2014). These papers do not support use of these techniques to rehabilitate streams permanently lost or degraded by mining at the Pebble deposit.

- Magnitude of restoration is likely not enough. There is little evidence that unaltered and high-functioning habitats such as those in the affected watersheds can be made substantially better. Roni and Beechie (2012) observed that when and where positive responses to restoration have been observed, it has primarily been in systems where habitat had been greatly simplified due to land clearing, road building, channelization, or other human activities (e.g., Ogston et al. 2015). Furthermore, with the exception of downstream barrier removal (e.g., Pess et al. 2012) or barrier modification, EPA is aware of no instances where restoration approaches yielded significant improvements in fish populations in highly functional watersheds with minimal human modification. These papers do not support the position that existing unaltered/undegraded fish habitats could somehow be improved by use of these techniques.

- Population response is not demonstrated. Even in watersheds where significant habitat rehabilitation efforts have been undertaken, a corresponding salmon response at the population scale has been elusive (Bennett et al. 2016).

- It is preferable to protect than to restore. Many authors have stated that based on lessons learned regarding the difficulty of restoring fish habitat once it has been degraded, priority should always be given to protecting existing high-quality habitat because it is much more effective and efficient to protect than to restore (Beechie et al. 2008).

In Canada, the Department of Fisheries and Oceans evaluated the efficacy of fish habitat compensation projects in achieving the conservation goal of no net loss (Harper and Quigley 2005a, Harper and Quigley 2005b, Quigley and Harper 2006a, Quigley and Harper 2006b). Quigley and Harper (2006a) showed that 67 percent of compensation projects resulted in net losses to fish habitat, 2 percent resulted in no net loss, and only 31 percent achieved a net gain in habitat area. Quigley and Harper (2006a) concluded that habitat compensation in Canada was, at best, only slowing the rate of fish habitat loss. Quigley and Harper (2006b) showed that 63 percent of projects resulted in net losses to aquatic habitat productivity, 25 percent achieved no net loss, and only 12 percent provided net gains in aquatic habitat productivity. Quigley and Harper (2006b) concluded "the ability to replicate ecosystem function is clearly limited."

Quigley and Harper (2006b) and Quigley et al. (2006) highlight the need for improvements in compensation science, as well as institutional approaches, such as better project planning, monitoring, and maintenance. Findings from Quigley and Harper (2006a and 2006b) are echoed in a 2016 study of marsh and riparian habitat compensation projects constructed within the Fraser River Estuary from

1983 to 2011; this study found that only 33 percent of compensation sites were meeting biological and functional goals, even after many decades (Lievesley et al. 2016).

Although there are clearly opportunities to improve the performance of fish habitat compensation projects, Quigley and Harper (2006b) caution the following:

> It is important to acknowledge that it is simply not possible to compensate for some habitats. Therefore, the option to compensate for HADDs [*harmful alteration, disruption or destruction to fish habitat*] may not be viable for some development proposals demanding careful exploration of alternative options including redesign, relocation, or rejection.

SECTION 5. CONCLUSIONS

PLP and other commenters suggested an array of measures over the past decade as having the potential to compensate for adverse impacts on wetlands, streams, and fishes from the discharge of dredged or fill material associated with developing the Pebble deposit. EPA evaluated these measures for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this final determination to an acceptable level.

SECTION 6. REFERENCES

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